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Vol. XXVIII SECTION-B Part III

CONTRIBUTIONS TO OUR KNOWLEDGE OF DIGENETIC TREMATODES*—III

By

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(Read at the Annual Session at Jabalpur on 27th December 1957)

Family *Notocotylidae* Lühe, 1909.

Subfamily *Notocotylinae* Kossack, 1911.

Paramonostomum fulicai sp. nov.

A single specimen of this species was collected from the caeca of a common coot, *Fulica atra* Linnaeus, obtained from the market at Lucknow.

The body (Fig. 1*a*) is oval, round at the posterior end but bluntly pointed at the anterior end. It measures 2·4 mm. in length and 1·16 mm. in width in the middle region. The cuticle is studded with scale-like spines. The oral sucker is subterminal measuring 0·215 mm. in diameter.

The mouth leads into a short oesophagus measuring 0·078 mm. in length. The oesophagus divides into intestinal caeca at a distance of 0·332 mm. from the anterior extremity of the body. The intestinal caeca run towards the posterior extremity of

* Part of the thesis accepted for the degree of Doctor of Philosophy at the University of Lucknow.

the body where they are greatly concealed by the dense uterine coils and testes. Eventually they emerge behind the testes and terminate at a distance of 0·199 mm. from the posterior extremity of the body.

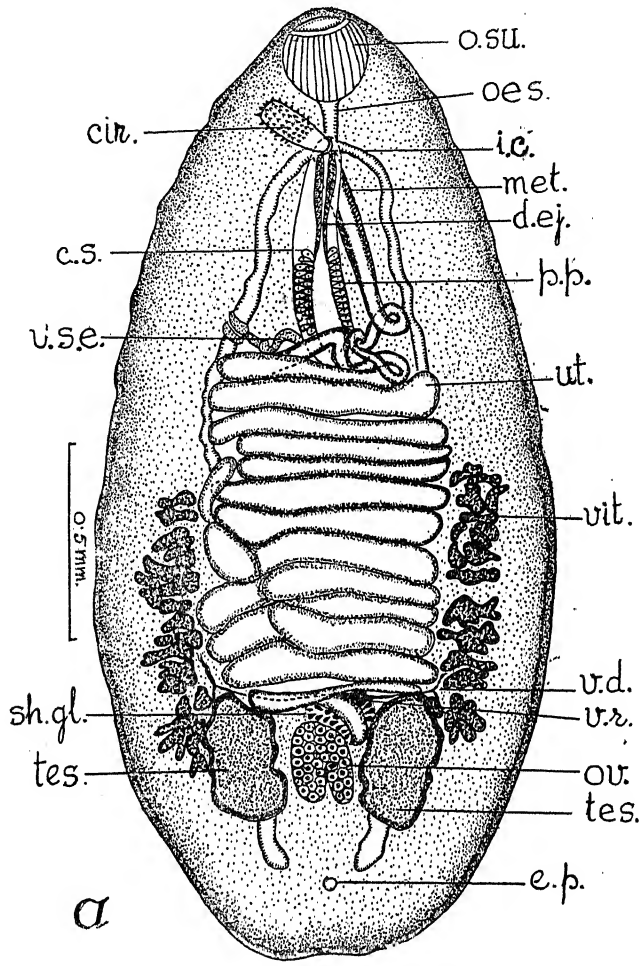


Fig. 1. *Parcmonostomum fulicai* sp. nov.
a., Ventral view of the entire specimen.

The testes are symmetrically located one on either side of the ovary in the posterior region of the body. They are ovoid structures with crenated margins and measure 0·332 × 0·199 mm. each. The vasa efferentia originating from the testes meet to form a long vas deferens which is masked by the dense uterine coils. The vas deferens runs forward and, at the level of the posterior region of the cirrus sac (Fig. 1*a*), enlarges to form a convoluted vesicula seminalis, part of which is enclosed within the cirrus sac as the vesicula seminalis interna while the remaining part lies outside as the vesicula seminalis externa. The cirrus sac is an elongated club-

shaped structure extending behind from the level of oesophageal bifurcation to a short distance in front of the equatorial line of the body and also the vitellaria. It measures 0·564 mm. in length. The vesicula seminalis interna lies in the basal part of the cirrus sac. It is continued into a pars prostatica which is thickly surrounded by prostatic cells and terminates in a ductus ejaculatorius. The cirrus is a tuberculated structure and is everted through the genital pore situated ventrally below the oesophageal bifurcation. The everted cirrus measures 0·205 mm. in length and 0·070 mm. in width.

The ovary is median and intertesticular in position. It is posteriorly notched and measures 0·182 mm. × 0·149 mm. The vitellaria are well-developed and are lateral in position. They extend posteriorly almost from the equatorial line of the body upto the sides of the anterior region of testes. The shell-gland mass lies directly in front of the ovary. Laurer's canal is present. The dense uterine coils are preovarian, mostly intercaecal but partly overlapping the intestinal caeca. They extend anteriorly upto the posterior region of the cirrus sac. Uterine coils are about a dozen in number. Eventually the uterus is continued into a well-developed muscular metraterm (Fig. 1*b*) which measures 0·348 mm. in length and is roughly two-thirds the length of the cirrus sac. It opens to the exterior through the common genital pore. The eggs are small with two long filaments, one at each pole, and measure 0·0182-0·0208 mm. ×0·0104-0·0130 mm. exclusive of the filaments.

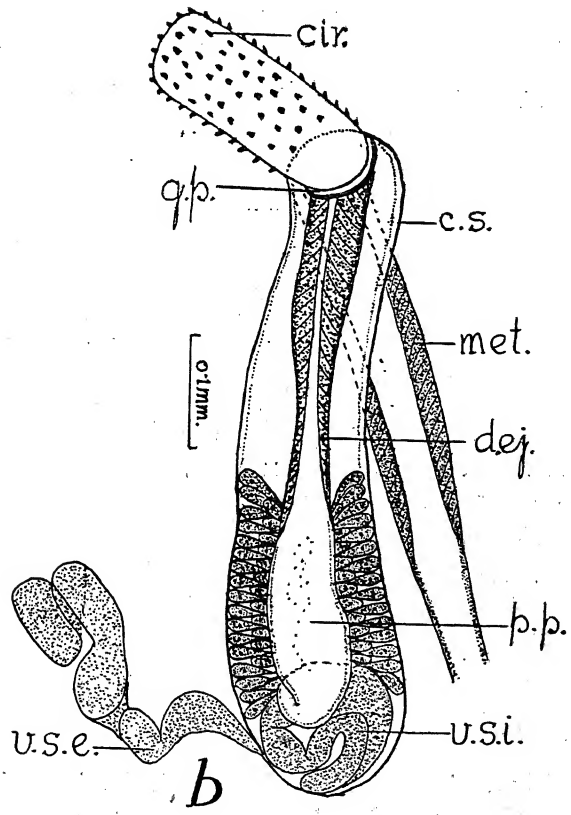


Fig. 1 *b*., Cirrus sac and metraterm.

The excretory pore lies mesially on the dorsal side slightly in front of the posterior extremity of the body.

DISCUSSION

The genus *Paramonostomum* Lühe, 1909, includes about a dozen species of which *P. alveatum* (Mehlis, 1846) Lühe, 1906; *P. pseudalveatum* Price, 1931, and *P. parvum* Stunkard and Dunihue, 1931, closely resemble the form described by the writer. From these species, the present form can be distinguished by the large size of its body and also by its tuberculated cirrus. It can be further distinguished from *P. pseudalveatum* by its vitellaria which in the present form do not extend anteriorly upto the level of the cirrus sac but they do so in *P. pseudalveatum*, and also by the position of its genital pore which is not situated behind the oral sucker as it is in *P. pseudalveatum* but at the oesophageal bifurcation. The present form can also be distinguished from *P. parvum* by the position of its genital pore at the oesophageal bifurcation, extension of its vitellaria upto the equatorial line of the body, and lastly by the size of its eggs which are smaller.

Paramonostomum nettioni sp. nov.

About a dozen specimens of this species were obtained from the rectum of a common teal *Nettion crecca* (Lin.), bought from the market at Lucknow.

The body (Fig. 2) is elongated, round at the posterior end but slightly tapering towards the anterior extremity. It measures 1·66-1·90 mm. in length and 0·498-0·581 mm. in maximum width at the postequatorial region of the body. Extremely small scale-like spines are present on the body. The oral sucker is subterminal and ventral in position, measuring 0·067-0·094 mm. × 0·086-0·108 mm.

The mouth leads into a moderately long oesophagus measuring 0·113-0·140 mm. in length. The oesophagus divides into intestinal caeca at a level about 0·166-0·199 mm. from the anterior extremity of the body. The intestinal caeca run backwards and terminate at the level of the posterior ends of the testes. They come close to each other in the region of gonads.

The testes are equal or subequal, extracaecal, and symmetrically placed one on either side of the ovary. They are either lobed or with crenated margins. The right testis measures 0·332-0·415 mm. × 0·149-0·182 mm., while the left one 0·265-0·332 mm. × 0·149-0·166 mm. The vasa efferentia and the vas deferens are obscured by the uterine coils. The vesicula seminalis is a convoluted structure, part of which lies outside the cirrus sac as the vesicula seminalis externa while the remaining part is enclosed as the vesicula seminalis interna. The cirrus sac is a long club-shaped structure measuring 0·498-0·581 mm. in length. It extends backwards beyond the anterior third of the body. The vesicula seminalis interna is continued into a short but distinct pars prostatica which is thickly surrounded by prostatic cells. The pars prostatica leads into a long and narrow ductus ejaculatorius which terminates in an aspinose cirrus. The genital pore is placed close behind the oral sucker.

The ovary is lobate, intercaecal and intertesticular in position. It measures 0·166-0·182 mm. × 0·099-0·132 mm. The vitellaria are extracaecal and commence slightly behind the equatorial line of the body and extend upto the anterior region

of the testes. The transverse vitelline ducts arise from the sides of the body at the level of the anterior ends of the testes. They run obliquely backwards and inwards, and meet mesially to form a vitelline reservoir. The shell-gland mass is situated immediately in front of the ovary. The vitelline reservoir lies ventral to the shell-gland mass. Laurer's canal and receptaculum seminis uterinum are present ; the latter is, however, greatly masked by the uterine coils in most of the specimens. The transverse uterine coils, twelve to fourteen in number, are compact and are limited to the intercaecal field. The metraterm, though differentiated from the uterus, is not well-developed. It runs forward ventral to the narrow terminal part of the cirrus sac with which it opens to the exterior through the genital pore. The metraterm is about half the length of the cirrus sac. It measures 0·249-0·282 mm. in length. The eggs are small, provided with two long polar filaments, and measure 0·0162 mm. × 0·0094 mm. exclusive of the filaments.

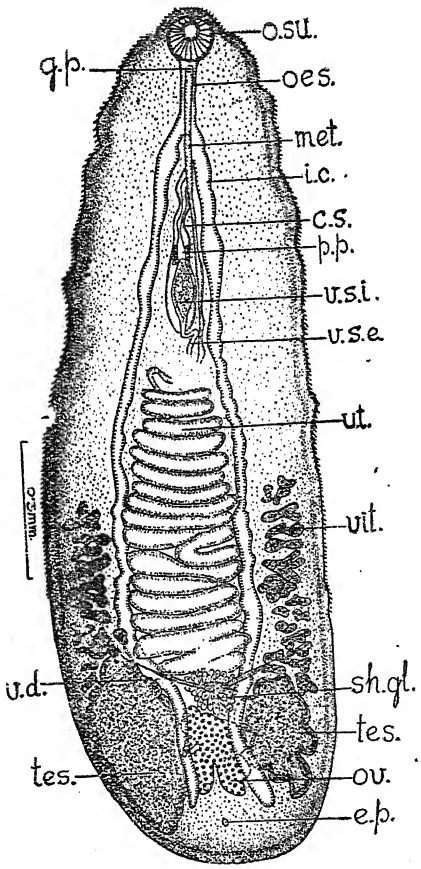


Fig. 2. *Paramonostomum nettioni* sp. nov.
(ventral view)

The excretory pore is dorsal and lies behind the ovary.

DISCUSSION

Of all the species of the genus *Paramonostomum* Lühe, 1909, including the new species described in the preceeding pages, the form under discussion closely resembles the Indian species *P. querquedulum* Lal, 1936, and *P. casarcum* Lal, 1936, but it can be distinguished from both by the number of its uterine coils and also by its vitellaria which do not extend upto the middle of the body in the present form whereas in the said species the vitellaria extend forward upto or beyond the middle of the body. It can be further distinguished from *P. querquedulum* by the absence of the lateral diverticula of the intestinal caeca, position of the genital pore immediately behind the oral sucker, and size of the eggs. From *P. casarcum*, the present form can also be distinguished by the small size of its body and of other structures, presence of a receptaculum seminis uterinum, and character of testes which are not deeply lobate.

Key to the Indian species of the genus *Paramonostomum* Lühe, 1909.

I. Genital pore in front of oesophageal bifurcation II
Genital pore not in front of oesophageal bifurcation IV

II. Intestinal caeca with short diverticula ... *P. querquedulum* Lal, 1936.
Intestinal caeca without diverticula ... III

III. Receptaculum seminis uterinum present, Testes not deeply lobate ... ... *P. nettioni* sp. nov.
Receptaculum seminis uterinum absent, Testes deeply lobate ... ... *P. casarcum* Lal, 1936.

IV. Metraterm two-thirds the length of the cirrus sac. ... ... *P. fulicai* sp. nov.
Metraterm nearly as long as the cirrus sac. *P. microstomum* Moghe, 1932

Notocotylus parviovatus Yamaguti, 1934.

Syn. *Notocotylus orientalis* Ku, 1937.

This species was originally described by Yamaguti (1934) from Japan from the caeca of a bird, *Olor bewicki jankowskii* (Alpheraky). Subsequently Ku (1937) described another closely allied species from the caeca of *Melanonyx fabates serrirostris* Swinhoe from China under the name *Notocotylus orientalis*. Dubois (1951a) in his revision of the genus *Notocotylus* Diesing, 1839, merged *N. orientalis* into synonymy with *N. parviovatus* Yamaguti, 1934. The present writer is in full agreement with Dubois (1951a) in regarding *N. orientalis* as a synonym of *N. parviovatus* as there is not much difference between them.

The writer obtained a large number of specimens of this trematode from the caeca of *Anser anser* (Lin.), shot in the vicinity of the district Hardoi, U.P. The present find of this species extends the range of its geographical distribution from China and Japan to India. A brief description of this form is given below.

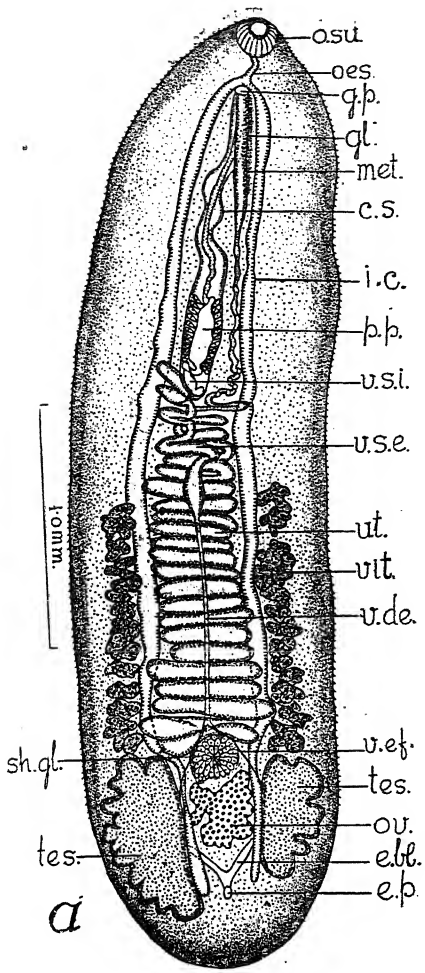


Fig. 3. *Notocotylus parviovatus* Yamaguti.

a., Ventral view of an entire specimen.

The body (Fig. 3*a*) is spiny elongated, broadly round at the posterior extremity but slightly pointed towards the anterior extremity. It measures 2·905-4·282 mm. in length and 0·879-1·062 mm. in width. Of the three rows of ventral glands, two lateral rows include 23-25 glands whereas the median row 20 or 21 glands. The oral sucker measures 0·108-0·148 mm. × 0·162-0·170 mm.

The mouth leads into a short oesophagus measuring 0·067-0·089 mm. in length. The oesophagus divides into intestinal caeca at a distance of 0·215-0·249 mm. from the anterior extremity of the body. The intestinal caeca run posteriorly and in the region of gonads, they turn inwards, and run by the sides of ovary almost upto the posterior ends of the testes.

The testes are elongated lobed structures symmetrically situated, one on either side of ovary, at the posterior extremity of the body. They may be equal or

unequal in size. The right testis measures 0·498-0·697 mm.×0·249-0·332 mm. while the left one 0·464-0·614 mm.×0·249-0·282 mm. The cirrus sac is a long club-shaped structure measuring 0·913-1·494 mm. in length. It extends backwards from behind the oesophageal bifurcation to a short distance in front of the equatorial line of the body, but does not reach the level of vitellaria. The vesicula seminalis interna, smaller than vesicula seminalis externa, is confined to the broad basal part of the cirrus sac. It is continued into a large pars prostatica which is well differentiated and is thickly surrounded by prostatic cells. The ductus ejaculatorius is a long narrow structure. It terminates in a cirrus which is beset with minute spines.

The ovary is irregularly lobed and intertesticular in position, measuring 0·215-0·298 mm.×0·182-0·265 mm. The vitellaria are well-developed, lateral and extracaecal in position. They extend back nearly from the middle of the body upto the anterior ends of testes. The shell-gland mass lies immediately in front of the ovary and measures 0·132-0·182 mm.×0·166-0·182 mm. Laurer's canal is present. The compact transverse uterine coils, usually eighteen to twenty in number, are preovarian and intercaecal. The metraterm is a well differentiated structure with which are associated numerous prominent glandular cells (Fig 3b) which form a cellular coat as described by Yamaguti (1934). The metraterm is

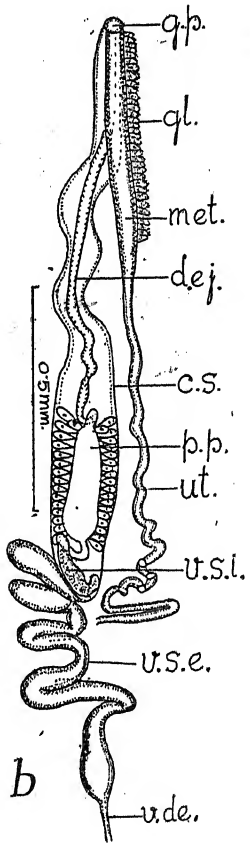


Fig. 3 *b*., Cirrus sac and metraterm.
(Glands shown only on one side of metraterm.)

about half the length of the cirrus sac and measures 0·415-0·664 mm. in length. The eggs measure about 0·0130 mm. × 0·0093 mm. and are provided with a long filament at each pole.

The excretory pore is dorsal and lies behind the ovary. It leads into a very short stem which immediately divides into two cornua.

Family *Cyathocotylidae* Poche, 1925.

Subfamily *Cyathocotylinae* Mühling, 1898.

Cyathocotyle phalacrocoraxi sp. nov.

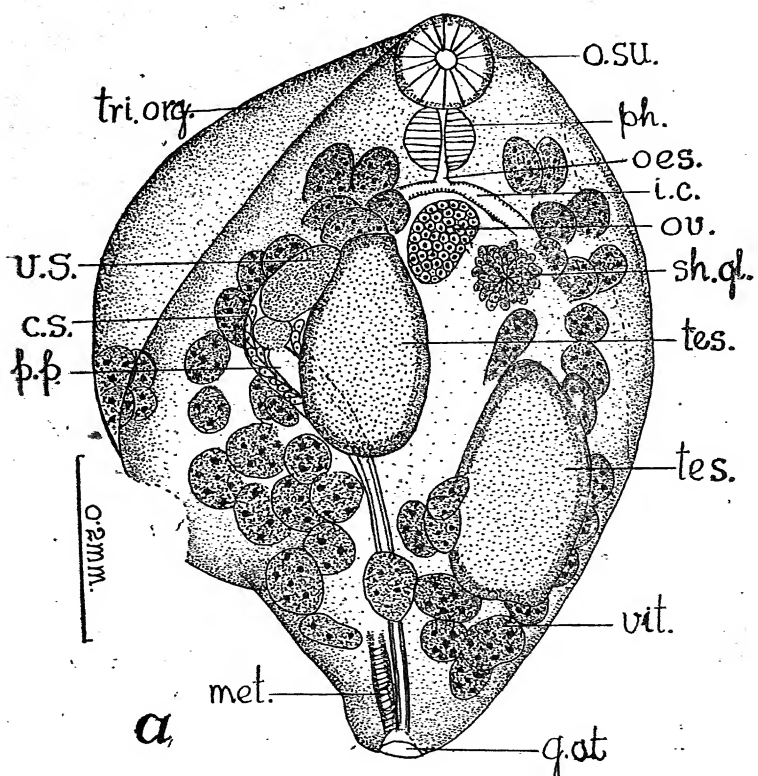
About half a dozen specimens of this species were obtained from the intestine of a little cormorant, *Phalacrocorax niger* (Vieillot) shot in the environs of the district Hardoi, U.P.

The body (Figs. 4 a, *b*) is aspinose, flattened, broadly ovate, measuring 0·705-0·763 mm. in length and 0·448-0·630 mm. in width at the middle region. The enormously developed tribocytic organ having a large central concavity occupies almost the whole ventral surface of the body, and measures 0·498-0·630 mm. in transverse axis and 0·365-0·431 mm. in longitudinal axis. There are scattered deeply staining gland cells in its wall. The oral sucker is ventral and terminal in position, and measures 0·067-0·088 mm × 0·093-0·109 mm. The ventral sucker is distinctly smaller than the oral sucker and measures about 0·059 mm × 0·065 mm. It is clearly seen from the ventral side (Fig. 4*b*) of the body.

The mouth leads through a very short prepharynx (which is usually contracted and not visible in whole mounts) into a well developed globular or subglobular pharynx (Fig. 4*a*) measuring 0·052-0·065 mm × 0·062-0·065 mm. As the oesophagus is very short, the intestinal caeca seem to arise almost immediately behind the pharynx (Fig. 4*a*) at a distance of 0·117-0·156 mm. from the anterior extremity of the body. The intestinal caeca are only traceable for a short distance as they are obscured posteriorly by the vitellaria.

The testes are round or elongate oval structures, symmetrical or oblique in position. They measure about 0·249 mm. × 0·132 mm. when elongate oval, or 0·130-0·156 mm. in diameter when round. The cirrus sac is very long and extends obliquely forward from the narrow posterior extremity of the body towards the left side beyond the middle region. It measures about 0·498 mm. in length. It encloses a bipartite vesicula seminalis which is full of sperms. The proximal part of the vesicula seminalis is large while the distal part is small. The vesicula seminalis is continued into a pars prostatica surrounded by prostatic cells and terminates in a long ejaculatory duct. The male genital duct eventually opens along with the metraterm into a funnel-shaped genital atrium situated at the tip of the conical posterior end of the body.

The ovary is round or oval, and measures about 0·096 mm. in diameter when round, or 0·096 mm × 0·059 mm. when oval. It is rather variable in position. It may be median between the testes, or lateral in position. The vitellaria consist of large compact follicles which are arranged more or less in the form of a wreath around the tribocytic organ. A shell gland mass is present. A muscular matraterm is present which opens into the genital atrium. A single egg was found in the uterus of one specimen. It measures 0·0715 mm × 0·0468 mm.



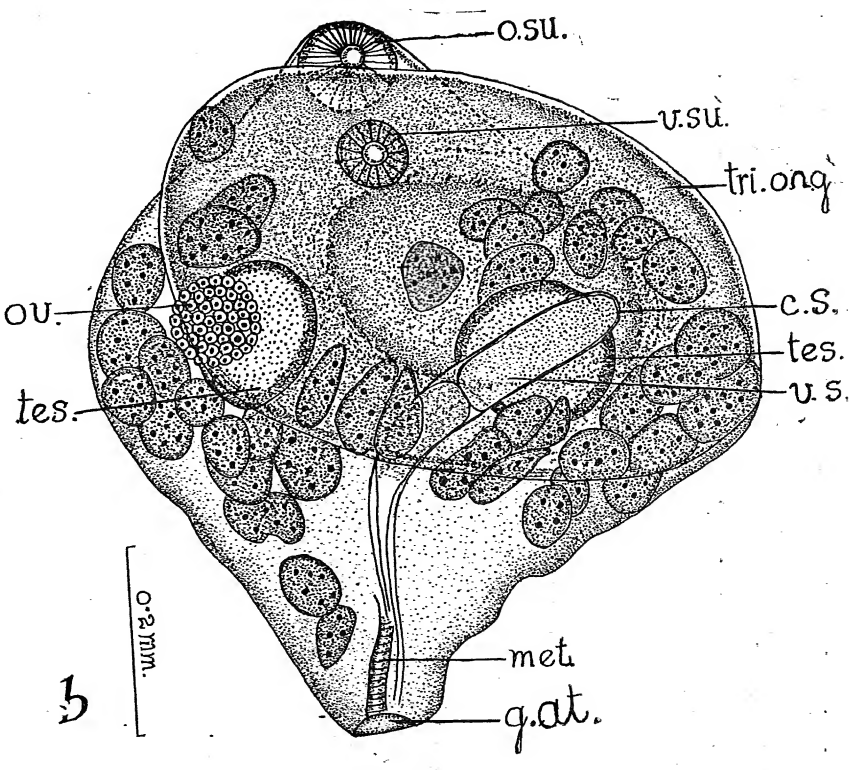


Fig. 4. *Cyathocotyle phalacrocoraxi* sp. nov.

a., Dorsal view of a specimen especially showing the parts of alimentary canal.

b., Ventral view of another specimen especially showing tribocytic organ and ventral sucker.

DISCUSSION

The genus *Cyathocotyle* Mühling, 1896, includes about a dozen species. The present form closely resembles *C. prussica* Muhl., 1896; *C. melanittae* Yamaguti, 1934 and *C. anhingi* Vidyarthi, 1948. It can be distinguished from *C. prussica* by its prepharynx and short oesophagus, absence of spines, relative size of its suckers and pharynx, and lastly by its smaller eggs. The present form differs from *C. melanittae* in having an aspinose body, comparatively large but few vitelline follicles, and smaller eggs. It also differs from the Japanese species in the absence of a tubular genital atrium. It can be chiefly distinguished from *C. anhingi* by its ventral sucker being markedly smaller than the oral sucker, its short oesophagus and muscular metraterm, and also by the absence of a muscular sucker-like genital atrium.

Key to the Indian species of the genus *Cyathocotyle* Mühling, 1896.

I.	Cirrus sac extends forward upto or beyond the middle of the body ...	II
	Cirrus sac does not extend forward upto the middle of the body ...	III
II.	A sucker-like genital atrium present. Oral and ventral suckers are roughly equal in size	*C. anhingi* Vidyarthi, 1948.
	A sucker-like genital atrium absent. Oral sucker distinctly larger than ventral sucker	*C. phalacrocoraxi* sp. nov.
III.	Tribocytic organ half the width of the body	*C. calvusi** Verma, 1943.
	Tribocytic organ more than half the width of the body	*C. indica* Mehra, 1943.

Subfamily *Prohemistominae* Lutz, 1935.

Mesostephanus neophroni sp. nov.

Half a dozen specimens of this species were obtained from the intestine of a white scavenger vulture, *Neophron percnopterus gingianns* (Lath.), shot in the environs of the district Banaras, U. P.

The body (Figs. 5*a*, *b*) is pear-shaped, broad posteriorly and narrow antetiorly, with a short terminal caudal appendage (Fig. 5b) which is continuous with the rest of the body. It measures 0·830 – 1·162 mm. in length and 0·747 – 0·946 mm. in width at the middle region. The caudal appendage measures 0·132 – 0.166 mm. in length and 0·215 – 0·249 mm. in width. The integument is beset with extremely small spines. The lateral margins of the body are inrolled ventrally so as to form a pouch-like cavity. The tribocytic organ is a very large structure occupying almost the whole of the posterior two-thirds of the body. The oral sucker is terminal, measuring 0·065 – 0·078 mm. × 0·070 – 0·085 mm. The ventral sucker is distinctly smaller than the oral sucker, and measures 0·049 – 0·059 mm. × 0·065 – 0·078 mm. It is mesially situated at a distance of 0·265 – 0·398 mm. from the anterior extremity of the body, and is overlapped by the tribocytic organ.

*Mehra (1943) placed this species under the genus *Holostephanus* Szidat. The present writer is, however, inclined to retain it under the genus *Cyathocotyle* Muhling, untill fresh living specimens of this species are studied to ascertain its position under *Holostephanus*.

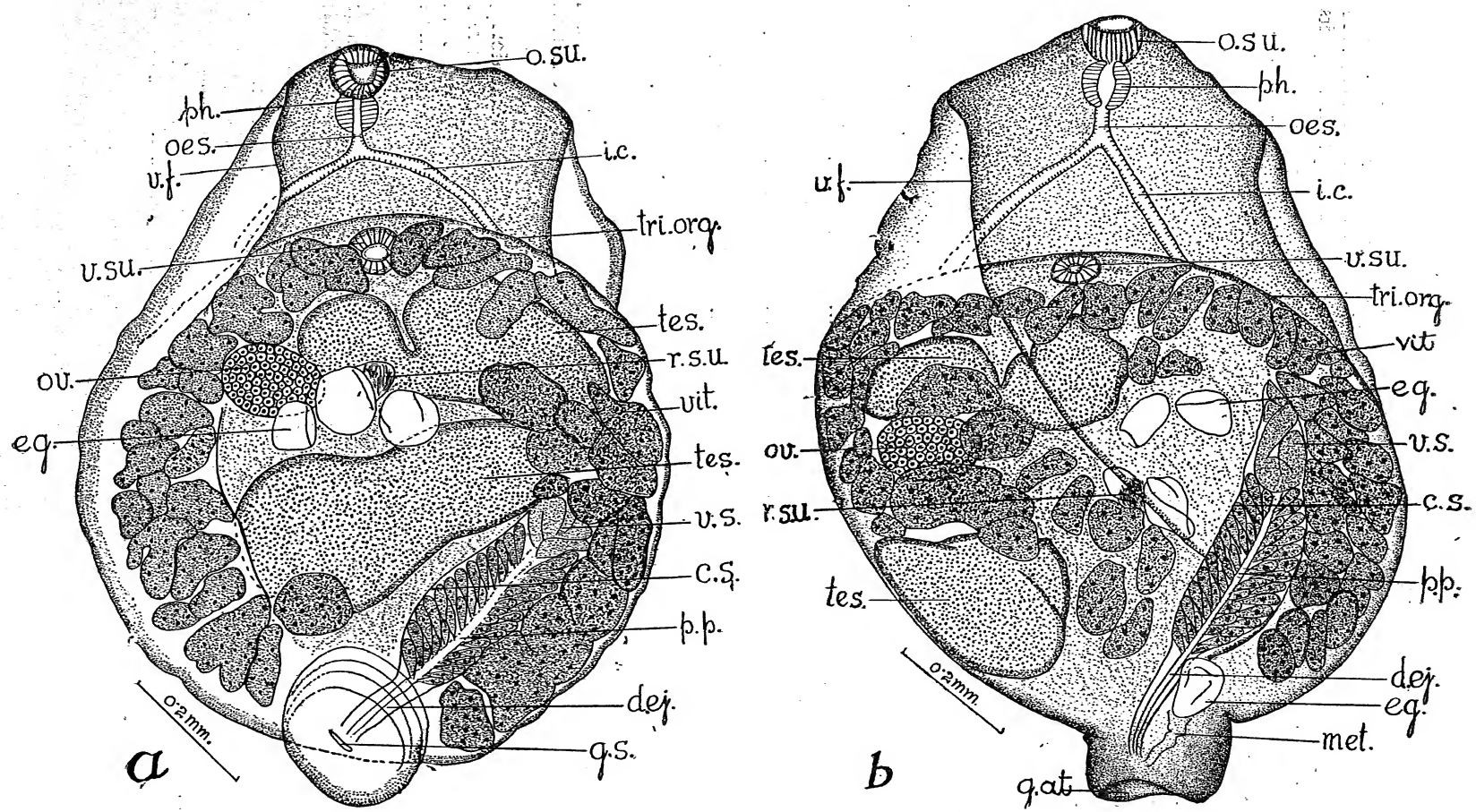


Fig. 5. *Mesostephanus neophron* sp. nov.

a., Ventral view of a specimen. (Ventral sucker made prominent.)

b., Ventral view of another specimen showing caudal appendage.

The mouth leads through a short prepharynx (not ordinarily visible in whole mounts) into a subglobular pharynx measuring 0·052 – 0·065 mm. × 0·065 – 0·078 mm. The oesophagus is short and measures 0·026 – 0·052 mm. in length. It divides into intestinal caeca about 0·149 – 0.182 mm. behind the anterior end of the body. The intestinal caeca are clearly seen only upto the anterior border of the tribocytic organ.

The testes are usually transversely elongated or oval structures and are tandem in position. The anterior testis which appears notched, measures 0·149 – 0·199 mm. in length and 0·348 – 0·448 mm. in width, while the posterior testis measures 0·166 – 0·249 mm. in length and 0·249 – 0·481 mm. in width. The cirrus sac is a well developed, club-shaped structure measuring 0·481 – 0·630 mm. length. It extends obliquely forward usually towards the left side from the narrow posterior end upto the middle region of the body. It encloses a coiled vesicula seminalis which occupies the proximal third of its cavity. The vesicula seminalis is continued into a well-developed narrow pars prostatica which is thickly surrounded by prostatic cells and terminates in a ductus ejaculatorius.

The ovary is round or oval in shape, and usually dextral and intertesticular in position. It measures 0·083 – 0·104 mm. × 0·124 – 0·150 mm. The vitellaria consisting of large follicles form almost a complete wreath around the periphery of the tribocytic organ. The shell-gland mass is not distinguishable. A receptaculum seminis uterinum is present. The uterus may contain 3 to 5 eggs which measure 0·0910 – 0·0962 mm. × 0·0650 – 0·0676 mm. The metraterm opens with the male genital duct into a funnel-shaped genital atrium located in the caudal appendage. The so called vaginal sphincter is absent.

DISCUSSION

Lutz (1935) created the genus *Mesostephanus* in which he included the following species: *Mesostephanus fajardensis* (Price, 1934), *M. appendiculatus* (Ciurea, 1916), *M. odhneri* (Travassos, 1916); *M. appendiculatoides* (Price, 1934), and *M. infecundus* Lutz, 1935. He mainly characterized the genus by a linguiform anterior body with its lateral margins folded ventrally and a small caudal appendage which represents the posterior part of the body. Szidat (1936) accepted the genus and designated *Mesostephanus fajardensis* as the type species. Subsequently several species were described under this genus by various workers. Dubois (1951 b) in his systematic revision of the strigeids has redefined the genus *Mesostephanus* Lutz, 1935. He has characterized the genus chiefly by the presence of a vaginal sphincter and has retained the following species under it, viz., *M. fajardensis* (Price, 1934) Lutz, 1935; *M. appendiculatoides* (Price, 1934), Lutz, 1935, *M. appendiculatus* (Ciurea, 1916) Lutz, 1935; *M. cubaensis* Alegret, 1941; *M. haliasturus* Tubangui et Masilungan, 1941 and *M. longisaccus* Chandler, 1950, as all these forms possess a vaginal sphincter. The other species which do not possess a vaginal sphincter viz., *M. milvi* Yamaguti, 1939; *M. indicum* Mehra, 1947, and *M. lutzi* Vidyarthi, 1948, have been transferred by Dubois (1951b) to the genus *Prohemistomum* Odhner which he has chiefly distinguished from *Mesostephanus* by the absence of a vaginal sphincter. Strangely, Dubois (1951b) has himself included *Mesostephanus fregatus* Tubangui et Masilungan, 1941, with a vaginal sphincter under the genus *Prohemistomum*. In fact, the term vaginal sphincter seems to have been ill-defined and it appears that some workers (Chatterje, 1940; Mehra, 1947) even do not make any distinction between a vaginal sphincter and metraterm, whereas other workers (Price, 1934; Tubangui et Masilungan 1941; Dubois 1951b) appear to regard an enlarged portion of the metraterm as a vaginal sphincter. In the opinion of the writer, this character is not of generic

importance and the distinction between the genera *Mesostephanus* Lutz and *Prohemistomum* Odhner should be based chiefly on the presence or absence of a caudal appendage as was previously done by Dubois (1938) himself and other workers, viz., Lutz (1935), Szidat (1936) and Mehra (1947). The transfer, therefore, of the species *Mesostephanus milvi* Yamaguti, 1939, *M. indicum* Mehra, 1947 and *M. lutzi* Vidyarthi, 1948, by Dubois (1951b) from *Mesostephanus* Lutz to *Prohemistomum* Odher is uncalled for.

Of the known species of the genus *Mesostephanus* Lutz, the present form shows some resemblance to *M. indicum* Mehra, 1947 and *M. indicus* Vidyarthi, 1948, but it can be distinguished from both these species by the large size of its tribocytic organ. In fact, this feature alone distinguishes the present form from all the known species. It can be further distinguished from *M. indicum* Mehra by its ventral sucker being smaller than the oral sucker and also by the more anterior extension of its cirrus sac, and from *M. indicus* Vidyarthi by its coiled vesicula seminalis.

Key to the Indian species of the genus *Mesostephanus* Lutz, 1930.

I. Tribocytic orgon half or less than half the width of the body..... II
Tribocytic organ more than half the width of the body.....III

II. Cirrus sac does not extend forward beyond posterior testis. Ventral sucker slightly larger than oral sucker.....*M. indicum* Mehra, 1947.
Cirrus sac extends forward upto anterior testis. Ventral sucker smaller than oral sucker.....*M. lutzi* Vidyarthi, 1948.

III. Vesicula seminalis tubular. Anterior testis entire.....*M. indicus* Vidyarthi, 1948.
Vesicula seminalis coiled, Anterior testis bilobed.....*M. neophroni* sp. nov.

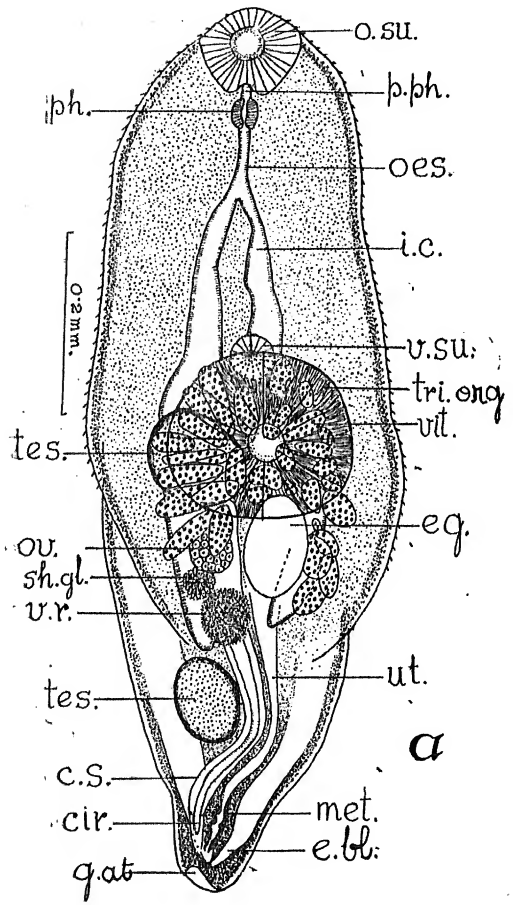
Subfamily *Gogatinae* Mehra, 1947.

*Gogatea incognitum** sp. nov.

A large number of specimens of this fluke were obtained from the intestine of an unidentifiable snake, the carcass of which was obtained from a dealer in snake skins at Banaras, U. P.

The body (Fig. 6a) is of a characteristic shape consisting of a fore-body and a hind-body; the fore-body has a flat sole-like appearance with a shallow ventral concavity, while the hind body is a bluntly conical structure held up in natural position at an acute angle from the posterior end of the dorsal side of the former. The fore-body is much larger than the hind body and is bluntly pointed anteriorly.

* The specific name is associated with the unknown serpent host.



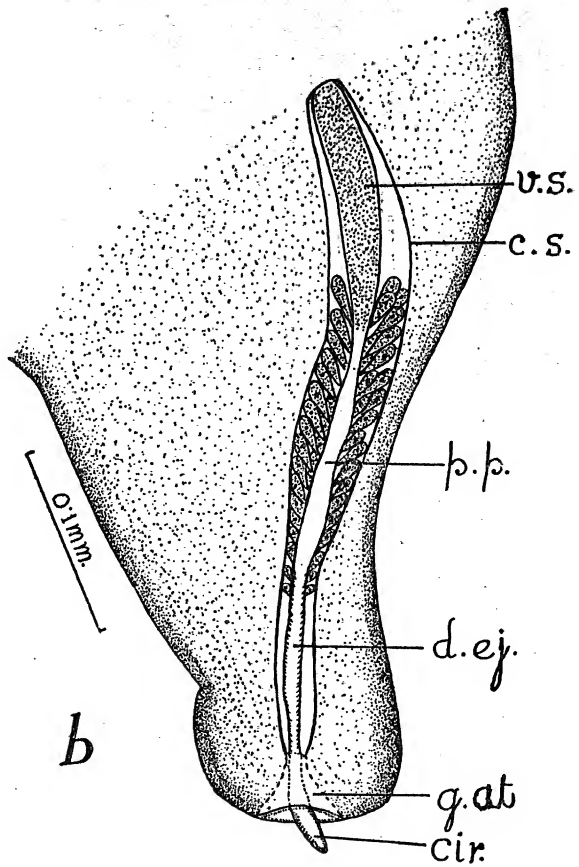


Fig. 6. *Gogatea incognitum* sp. nov.

a., Ventral view of a specimen.

b., Posterior region of a specimen showing cirrus sac with its enclosed structures.

The fore-body measures 0·664—0·747 mm. in length and 0·315 –0·365 mm. in width in the region of the tribocytic organ, while the hind body measures 0·298-0·464 mm. in length. The body in its entirety measures 0·847-1·080 mm. × 0·313-0·365 mm. Almost the entire fore-body, including the tribocytic organ, is densely covered with extremely small spines. The oral sucker is ventral and terminal in position, measuring 0·082-0·090 mm × 0·099-0·115 mm. The ventral sucker is a well-developed muscular structure, much smaller than oral sucker, and measures 0·041-0·052 mm. in diameter. It is situated near the middle of the fore-body close to the anterior border of the tribocytic organ, and its posterior half is usually masked by the latter. The tribocytic organ is almost circular with a central round opening and is located in the posterior half of the fore-body. It measures 0·215-0·249 mm. in diameter.

The mouth leads through a short but distinct prepharynx into a muscular pharynx measuring 0·036-0·041 mm. × 0·033-0·041 mm. The pharynx is distinctly smaller than the ventral sucker. The oesophagus is moderately long measuring 0·049-0·091 mm. in length. It divides into intestinal caeca at a distance of 0·182-0·232 mm. from the anterior end of the body. The intestinal caeca run posteriorly dorsal to the tribocytic organ, and terminate near the anterior border of the posterior testis.

The testes are round or oval, equal or subequal, and are tandem in position. The position of the testes relative to the two parts of the body depends on the state of contraction of the body. Normally the anterior testis is located in the fore-body dorsal to the tribocytic organ while the posterior one in the hind-body. Each testis measures 0·099-0·115 × 0·066-0·099 mm. The cirrus sac is an elongated club-shaped structure extending back from the region of the tribocytic organ upto the tip of the posterior extremity of the body where it opens into a genital atrium. It measures 0·365-0·415 mm. in length. The vesicula seminalis (Fig. 6b) is an elongated tubular structure occupying roughly the proximal third of the cirrus sac. It is continued as a narrow pars prostatica surrounded by the prostatic cells. The pars prostatica eventually leads into a ductus ejaculatorius which terminates in a cirrus. The genital atrium is a terminal infundibular structure through which the cirrus is everted (Fig. 6b).

The ovary is globular, subglobular, or even oval in shape. It is intertesticular in position, but may be median or lateral. It measures 0·046-0·052 mm. in diameter when round, or 0·057-0·064 mm. × 0·062-0·072 mm. when oval. The vitellaria composed of large follicles about 25 to 30 in number are arranged in two regular or irregular rows on either side of the body commencing from the level of the ventral sucker where they closely approach each other and extending posteriorly beyond the tribocytic organ upto the end of the fore-body. In a few specimens the follicles are found arranged in two parallel rows. The vitelline reservoir is very large, sometimes as large as the testes, and measures 0·083-0·099 mm. × 0·083-0·116 mm. Laurer's canal and shell-gland mass present. The uterus is short and runs posteriorly along the cirrus sac. The metraterm opens into the genital atrium. The eggs are large, one or two in number, and measure 0·1339 mm. × 0·0728 mm.

Excretory bladder is V-shaped (Fig, 6a) with long cornua extending far forward.

DISCUSSION

The present form conforms to the characters of the genus *Gogatea* created by Lutz (1935) for the reception of *Prohemistomum serpentium* Gogate, 1932. Szidat (1936) assigned one more species viz, *Prohemistomum joyeuxi* (Hughes, 1929) to this genus. Dubois (1938) created the genus *Szidatia* for the species *Gogatea joyeuxi* (Hughes, 1929) Szidat, 1936. Chatterje (1940) and Mehra (1947) did not accept the genus *Szidatia* and

they regarded *Szidatia* as a synonym of *Gogatea*. Dubois (1951b) in his revision of strigeids, however, still maintains *Szidatia* as a valid genus distinguishing it from *Gogatea* mainly by the shape of the tribocytic organ and disposition of the vitellaria in two parallel rows. Dollfus (1953) seems to follow Dubois (1951b) in regarding the genus *Szidatia* still valid and he also described a new species viz., *Szidatia nemethi* which he obtained from *Natrix viperina* in Morocco. The present writer is of the opinion that the distinguishing features taken into account by Dubois (1951) are not of sufficient generic importance. He, therefore, fully agrees with the views of Chatterje (1940) and Mehra (1947) in regarding the genus *Szidatia* as a synonym of *Gogatea*, and hence the species *Gogatea joyeuxi* is retained under the genus *Gogatea* Lutz. Consequently the subfamily *Gogatinae* established by Mehra (1947) for the genus *Gogatea* as a substitute for *Szidatinae* Dubois is recognized.

The present form can be readily distinguished from both *G. serpentium* (Gogate, 1932) Lutz, 1935, and *G. joyeuxi* (Hughes, 1929) Szidat, 1936, by the more anterior extension of its cirrus sac. It can be further distinguished from *G. serpentium* by its distinct prepharynx and well developed ventral sucker, and from *G. joyeuxi* by its circular tribocytic organ and also by the more anterior extension of its vitellaria. It can be distinguished from *G. nemethi* (Syn. *Szidatia nemethi* Dollfus, 1953) by the smaller size of its body and of other structures, relative size of its suckers and pharynx, presence of a prepharyx, number of eggs, and lastly by the comparatively large size of its eggs.

Mehra (1947) described a new variety viz., *indicum* of *Gogatea serpentium* from the intestine of *Natrix piscator* Schneider. The present form resembles this new variety from which it can be chiefly distinguished by the smaller size of its body and of other organs, relative size of its ventral sucker and pharynx, and presence of a prepharynx.

Family *Opisthorchiidae* Lühe, 1901, Emend. Braun 1901.

Subfamily *Opisthorchiinae* Looss, 1899.

Nigerina hardoiensis gen nov. et. sp. nov.

A number of specimens of this fluke were obtained on several occasions from the gall bladder and liver of the little cormorant *Phalacrocorax niger* (Vieillot) shot in the vicinity of the district Hardoi, U.P.

The body (Fig. 7) is long, shape being like a cricket bat, consisting of a short narrow almost cylindrical anterior part, and a long broad flattened posterior part. It measures 5·65-12·52 mm. in length and 0·852-1·033 mm. in maximum width at the posterior region. The integument of the body is entirely devoid of spines. The margins of the post-acetabular region of the body appear ruffled much like that of the cestode genus *Gyrocotyle* and form conical lateral projections. These projections present a stratified appearance like that of a starch grain. This ruffled appearance of the lateral margins of the body is extremely prominent in the living condition. The suckers are well developed and strongly muscular structures. The oral sucker is terminal measuring 0·196-0·246 mm. × 0·410-0·574 mm. The ventral sucker is situated towards the hind region of the anterior part of the body at a distance of 1·19-1·80 mm. from the anterior end and measures 0·328-0·459 mm × 0·410-0·459 mm.

The mouth leads into a well developed pharynx which measures 0·164-0·246 mm. × 0·180-0·278 mm. The oesophagus is short and appears bulbous measur-

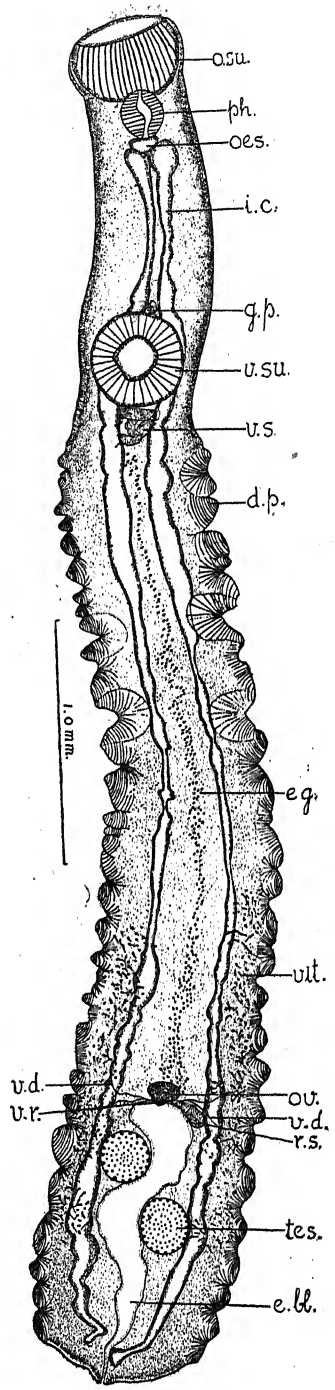


Fig. 7. *Nigerina hardoiensis* gen. nov., sp. nov.
(Ventral view.)

ing about 0·082-0·148 mm. in length. It divides almost immediately behind the pharynx into intestinal caeca which run upto the posterior extremity of the body.

The gonads are located in the posterior end of the body. The testes are globular or subglobular and are obliquely placed. The anterior testis measures 0·164-0·295 mm. × 0·164-0·246 mm. while the posterior one 0·164-0·278 mm. × 0·164-0·246 mm. The vesicula seminalis is a convoluted structure lying freely in the body parenchyma just posterior to the ventral sucker. A cirrus sac is absent. The genital pore is situated immediately in front of the ventral sucker.

The ovary is round or oval, situated a short distance in front of the anterior testis and measures 0·082-0·180 mm. × 0·115-0·180 mm. The vitellaria are weakly developed. The follicles are extremely small, mostly dendritic and are sparsely distributed in the lateral region of the posterior half of body upto the level of posterior testis. Two vitelline ducts on each side, one from the preovarian vitelline follicles and the other from the postovarian vitelline follicles, meet near the level of the ovary to form a short common transverse vitelline duct. The two common transverse vitelline ducts meet to form a small vitelline reservoir immediately behind the ovary. The shell-gland mass is a well developed, fairly compact structure lying close to the ovary. Laurer's canal and receptaculum seminis are present. The course of the uterine coils is not clearly seen, but the eggs are distributed in the intercaecal field in front of the ovary. The eggs are extremely small, thin-shelled, non-operculate, and measure 0·0247-0·0260 mm. × 0·0130-0·0150 mm.

The excretory pore is terminal, leading into a sigmoid excretory bladder which runs forward between the testes upto the ovary.

DISCUSSION

It is evident from the foregoing account that this fluke belongs to the family *Opisthorchiidae* Lühe, 1901, emend. Braun, 1901.

The form is rather unique amongst the known genera of the family *Opisthorchiidae* in having the margins of the postacetabular region of the body ruffled forming conical lateral projections which have a stratified character. In the opinion of the present writer, this peculiar feature has more than a specific importance. The writer, therefore, proposes to create a new genus, *Nigerina* with *N. hardoiensis* as its genotype for this form. The genus is assigned to the subfamily *Opisthorchiinae* Loose due to the eggs being confined to the postacetabular region of the body.

Generic diagnosis of *Nigerina* gen. nov.

Opisthorchiidae: *Opisthorchiinae*: Body elongated consists of two parts, a short narrow almost cylindrical anterior part and a long broad flattened posterior part. Suckers large and strongly muscular. Ventral sucker located at the end of the anterior part of body. The margins of the postacetabular region of the body appear ruffled forming conical lateral projections which have a stratified character. Pharynx well developed. Oesophagus short. Intestinal caeca terminate at the posterior end of body. Gonads located in the posterior end of body. Testes oblique and entire. Vesicula seminalis lies free in the parenchyma near the posterior border of ventral sucker. Cirrus sac absent. Ovary pretesticular. Vitellaria weakly developed, confined to the posterior half of the body. Uterine coils preovarian, intercaecal and postacetabular. Receptaculum seminis and Laurer's canal present. Shell-gland mass well-developed. Eggs small, Excretory bladder sigmoid passing between the testes upto the ovary.

Habitat : Parasites of the liver and gall-bladder of birds.

Genotype : *Nigerina hardoiensis* sp. nov.

Subfamily *Metorchiinae* Lühe, 1901.

Metorchis nettioni sp. nov.

Only two specimens of this species were obtained from the gall-bladder of a common teal, *Nettion crecca* Linnaeus, bought from the market at Lucknow. With a view to obtaining additional specimens, several more host specimens were subsequently examined but without any result. The specimens of the fluke obtained are more or less of equal size.

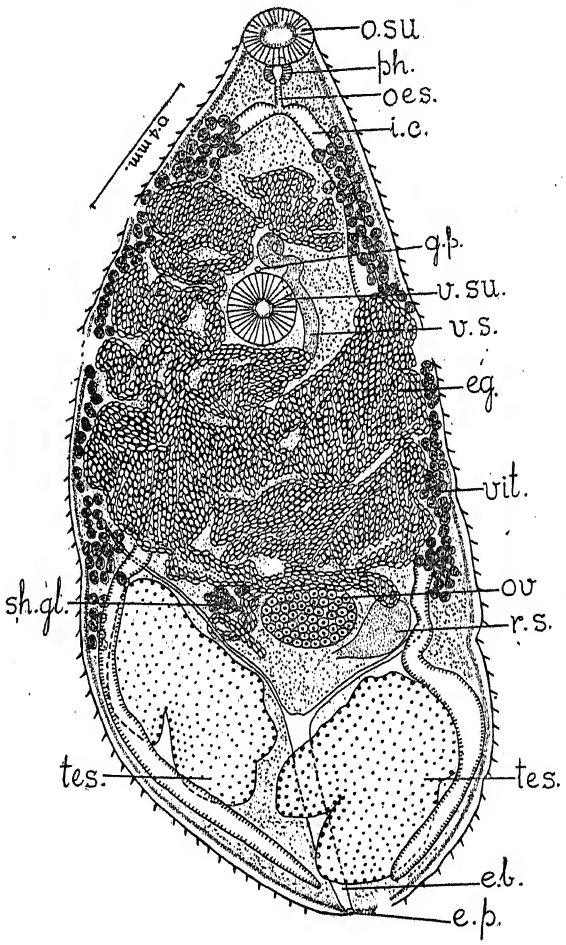


Fig. 8. *Metorchis nettrioni* sp. nov.
(Ventral view.)

The body (Fig. 8) is spinose, pear-shaped with a rounded posterior end and a bluntly pointed anterior end. It measures 2·373 mm. in length and 1·062 mm. in maximum width. The oral sucker is well developed and measures 0·132 mm. × 0 198 mm. The ventral sucker measures 0·198 mm. × 0·198 mm. It is

situated at a distance of 0·676 mm. from the anterior end of the body, and is slightly larger than the oral sucker.

The mouth leads into a pharynx which measures 0·065 mm. × 0·075 mm. The oesophagus is short and measures 0·065 mm. in length. It divides into two intestinal caeca which run backwards along the sides upto the posterior extremity of the body. They are greatly masked in the middle region of the body by the dense uterine coils.

The testes are large, lobate structures, obliquely placed in the posterior end of the body. The anteriorly placed right testis measures 0·606 mm. × 0·393 mm. while the more posteriorly placed left testis 0·557 mm. × 0·508 mm. The vesicula seminalis is a sinuous tubular structure situated on the left side of the ventral sucker. It narrows anteriorly and eventually opens to the exterior through the genital pore situated in the median line immediately in front of the ventral sucker.

The ovary is transversely oval, situated in the middle line in front of the posterior testis. It measures 0·247 mm. × 0·165 mm. The vitellaria are well-developed and consist of round follicles. They extend laterally almost from the level of oesophageal bifurcation upto the level of ovary. The shell-gland mass is located on the right side of ovary. The receptaculum seminis is a large pear-shaped structure situated on the left side of ovary, just in front of the posterior testis. It measures 0·165 mm. × 0·123 mm. The uterine coils are extensively developed and are closely packed. They occupy almost the entire space between the oesophageal bifurcation and ovary extending laterally into the extracaecal field. The eggs are operculate and measure 0·026-0·028 × 0·013-0·015 mm.

DISCUSSION

Of all the species of the genus *Metorchis* Looss, 1899, the present form closely resembles *Metorchis xanthosomum* (Creplin, 1846) Braun, 1902, from which it can be distinguished by the size of its body, suckers and eggs. Moreover, in the present form, the ventral sucker is slightly larger than the oral sucker, whereas in *M. xanthosomum* the ventral sucker, as given by various authors, is always smaller than oral sucker. The writer, therefore, feels that the present form represents a distinct species.

ABBREVIATIONS USED IN FIGURES

cir., cirrus; *c.s.*, cirrus sac; *d.ej*, ductus ejaculatorius; *e.p*, excretory pore; *e.bl.*, excretory bladder; *gl.*, glands; *g.p.*, genital pore; *g.at.*, genital atrium; *i.c.*, intestinal caeca; *met.*, metraterm; *oes.*, oesophagus; *ov.*, ovary; *o.su.*, oral sucker; *ph.*, pharynx; *pph.*, prepharynx; *p.p*, pars prostatica; *r.s.*, receptaculum seminis; *r.s u.*, receptaculum seminis uterinum; *sh. gl.*, shell gland mass; *tes.*, testes; *tri. org.*, tribocytic organ; *ut.*, uterus; *vit.*, vitellaria; *v.d.*, vitelline duct; *v.de.*, vas deferens; *v.r.*, vitelline reservoir; *v.su.*, ventral sucker; *v.s.*, vesicula seminalis; *v.s.e.*, vesicula seminalis externa; *v.s.i.*, vesicula seminalis interna.

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ON A NEW SPECIES OF THE GENUS *ALLOCREADIUM* Looss, 1900, OF THE FAMILY ALLOCREADIIDAE Stossich, 1904, TREMATODA FROM THE INTESTINE OF *MASTACEMBALUS ARMATUS*

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INTRODUCTION

In this paper a new trematode *Allocreadium spindale*, n.sp. has been described. The worms were obtained from the intestine of a fresh water fish *Mastacembalus armatus* in the month of September, 1956 at Raipur. The work was carried out in the Zoological Laboratory of the College of Science, Raipur.

DESCRIPTION

The worm is spindle shaped, cream coloured showing active movements during the living condition. It is 2·81-5·05 mm. long and 0·46-0·99 mm. broad at the level of the ovary. The subterminal oral sucker is smaller than the ventral sucker and measures 0·18-0·25 × 0·15-0·22 mm. in size. The ventral sucker is cup-shaped and well developed measuring 0·28-0·43 × 0·21-0·38 mm. It lies at a distance of 0·35-0·59 mm. from the anterior end.

The prepharynx and the oesophagus are small but the pharynx is muscular, prominent and measures 0·06-0·11 × 0·06-0·09 mm. in size. The intestinal bifurcation lies at a distance of 0·29-0·41 mm. from the anterior end. The caeca have entire margins and extend upto the posterior end of the body.

The excretory pore lies at the posterior end of the body and leads into a long tubular bladder which extends upto the posterior level of the posterior testis. The genital pore is located above the acetabulum slightly to the right of the median line (Fig. 1).

The gonads lie in the posterior region of the anterior half of body. The two oval testes lie one behind the other, posterior to the ovary and are intercaecal. The anterior testis is located at a distance of 1·11-2·32 mm. from the anterior end and measures 0·27-0·5 × 0·28-0·32 mm. The posterior testis, 0·32-0·45 × 0·3-0·45 mm. in size, is bigger than the anterior testis and the distance between the two testis is 0·003-0·126 mm. The vasaefferentia arise from the anterior face of each testis and run straight towards the cirrus sac, where they meet with each other to form a small vasdeferens before opening into the vesicula seminalis.

The cirrus sac is a well developed organ placed obliquely on the left side between the intestinal bifurcation and the acetabulum. It is 0·36-0·45 mm. long and 0·11-0·18 mm. broad at the region of vesicula seminalis. It contains oval vesicula seminalis 0·15-0·19 × 0·1-0·11 mm. in size, parsprostatica 0·054-0·105 × 0·069-0·07 mm. and a muscular cirrus. A large number of prostate gland cells cover the region of parsprostatica.

The ovary is oval in shape, lying at a distance of 0·91-1·9 mm. from the anterior end. It measures 0·13-0·2 × 0·12-0·18 mm. and is located at about 0·06-0·24 mm. above the anterior testis slightly towards the left of the median line. The oviduct arises from the anterolateral margin of the ovary. The receptaculum seminis is well developed, elongated measuring 0·18-0·42 mm. in length and 0·05-0·11 mm. in breadth. It is lateral to the ovary towards the left side extending upto its posterior margin. The Laurer's canal is not clearly visible.

The vitelline glands consist of big oval follicles extending from a little infront of the ovary to the posterior end of the body. They liein the lateral regions upto the level of the posterior testis beyond which they occupy the whole of the body. The anterior extension of vitellaria is uneven as the left one extends more anteriorly than the right one. The transverse vitelline ducts lie above the anterior testis. They meet to form a well developed triangular yolk reservoir below the ovary. It measures 0·2-0·22 × 0·14-0·16 mm. From the yolk reservoir a small vitelline duct proceeds towards the ootype which is located above the ovary towards its right side. The uterus arises from the right lateral side of the ootype and undergoes two short transverse loops between the ovary and the acetabulum before opening at the genital pore.

The eggs are arranged in a single row in the uterus. They are comparatively big in size, oval in shape and very few in numbers (4-16), measuring 0·165-0·177 mm. in length and 0·105-0·12 mm. in breadth.

DISCUSSION

The above description of *Allocreadium spindale* n. sp. conforms to the revised characters of the genus *Allocreadium* in general (Yamaguti, 1953). However, the position of the gonads in the posterior region of the anterior half of the body in the present species is worth noting and necessitate, the elaboration of this character in the family Allocreadiidae. The genus *Allocreadium* has been divided into four subgenera: *Allocreadium, Cainocreadium, Peracreadium* and *Lepidauchen* (=*Polylekithum* Arnold, 1934). The new form comes under the subgenus *Allocreadium* on account of its having vitellaria in the hinder body region. It differs from all the known species of the genus in the location of the acetabulum, and the gonads which are comparatively more anterior and the larger size of the eggs which are arranged in a single row in the uterus. It differs from *A. isoporum* (Looss, 1894) Looss, 1902; *A. lobatum* Wallin, 1909; *A. handiai, A. nicolli, A. kosia,* and *A. mahasari* (all of Pande 1937-38); and *A. thapari* Gupta, 1950 in having acetabulum larger than oral sucker; and from *A. lobatum* Wallin, 1909 and *A. hasu* Ozaki, 1926 in the shape of the testes and the posterior extension of the uterus. It differs from *A. transversale* (Rud., 1802) Odhner, 1901 and *A. japonicum* Ozaki, 1926 in the length of the oesophagus, extension of vitellaria, the location of gonads and the acetabulum. It shows further differentiation from *A. nicolli, A. kusia, A. schizothoracis* and *A. mahaseri* in the possession of very small oesophagus, extension of vitellaria, and the position of genital pore. From *A. nemachilus* Kaw, 1950 the present species differs in having oesophagus very small, position of intestinal bifurcation, gonads receptaculum seminis, ootype and the uterine coils as well as extension of vitellaria.

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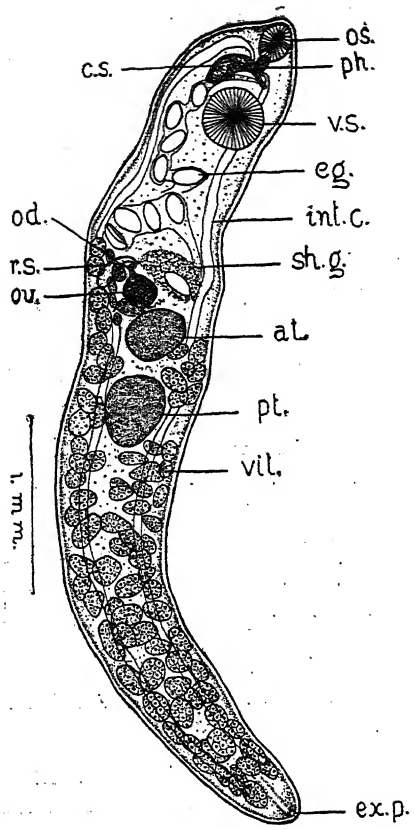
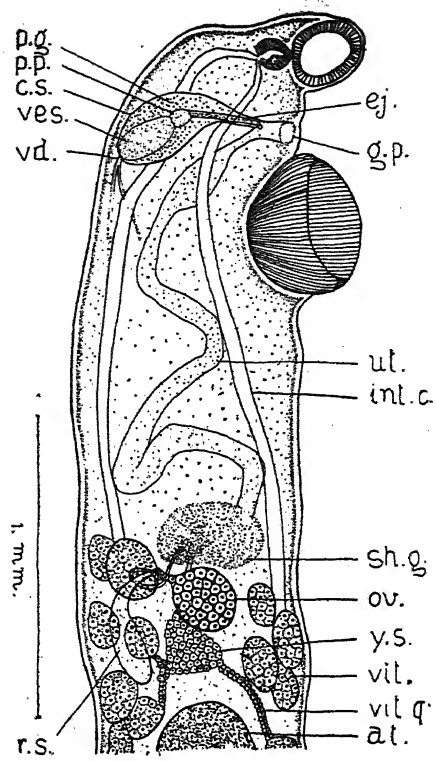


Text Figure 1.
Allocreadium spindale, n. sp.
Dorsal view.

at.	anterior testis
c. s.	cirrus sac
eg.	eggs
ej.	ductus ejaculatorious
gp.	gential pore
int. c.	intestinal caeca
O. S.	oral sucker
od.	oviduct
ov.	ovary
pg.	prostate gland
ph.	pharynx
pp.	parsprostatica.



Text Figure 2.
Allocreadium spindale, n. sp.
Reproductive Organs.

pt.	posterior testis
r. s.	receptaculum seminis
sh. g.	shell gland
ut.	uterus
ves.	vesicula seminalis
vit.	vitellaria
vitd.	vitelline duct.
v. s.	ventral sucker
vd.	vas deferens
ys.	Yolk reservoir.

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INFLUENCE OF INCREASE IN DAYLENGTH ON GROWTH BEHAVIOR, ROOT NODULATION AND FLOWER INITIATION IN *Cicer arietinum*

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INTRODUCTION

Allard and Garner (1940) made the statement that wild plants have been forced to adjust themselves to daylength and every successful plant represented an adjustment to this factor. There might be plants with rigid daylength requirements or indeterminate plants flowering in all lengths of day. Eaton (1931) found in soybeans, that the amount of growth and nodule development was in direct proportion to the length of day. Leonard (1926) reported the existence of a relation between photosynthesis and nitrogen fixation by nodules. Whyte (1946) postulated that a more active formation of nodules should occur on the roots of plants grown under long day than those grown under short day since the symbiotic relationship between leguminous plants and nodule bacteria was affected by the carbohydrate content of the plant. Cailahjan (1945) investigated this supposition in short day plant *Phaseolus vulgaris* and in long day plants, *Ervum lens* and *Phaseolus aureus*. Nodular mass was reported to be more intense in long day in all plants irrespective of class. The internal agent responsible was thought to be the high carbohydrate content in plants in long day conditions and the high content of growth hormones.

METHODS AND MATERIALS

Replicated randomised pot investigations were performed to investigate the effect of increase in daylength on growth and development of *Cicer arietinum* and on the number of nodular infection and mass of root nodules under the normal and supra-normal photo durations. The treatment comprised of the following durations :

(*i*) Normal daylength; average of 11·5 hours of natural illumination followed by 12·5 hours of darkness.

(*ii*) Sixteen hours of light and eight hours of darkness, alternating.

(*iii*) Light supply of 20 hours and darkness for four hours.

(*iv*) Continuous illumination for twentyfour hours *i.e.*, complete absence of dark period in the entire life cycle, from the initiation of treatment.

Photic exposures were administered from the fifteen-day seedling stage to the end of plants' life cycle, the plants exposed to different daylengths were separated by wooden partitions so that each received only the desired quantum of light.

In order to make up for the long daylength requirements normal sunlight was supplemented by artificial light. The source of light adopted was 1,000 watt Osram lamp with a reflector of the type recommended by Withrow (1943). Intensity of light in the vicinity of plants was maintained above the limiting value for photosynthesis (80,000 m.c.) *vide* the recommendation made by Singh and Kumar (1935). The control set of plants was exposed to normal day only. The temperature difference was kept at minimum such that the light effect may not be obviated.

Position effect was minimised by placing the plants at equal distance from the light source by adjusting the latter throughout, and rotating the pots, by hand, at fixed intervals. Cultural operations were kept similar in all the sets and the plants were watered in accordance with their needs depending on the size.

Average of four replicates of six plants each have been employed to represent the treatment effects. Standard error and critical difference due to treatments have been worked out and shown as S.E. and C.D. respectively.

EXPERIMENTAL RESULTS

Dry Matter Accumulation.

Maximum dry weight of tops was synthesised in the 16-hour set, followed by 20, 24-hour and normal exposures in succession (Table 1). The 11·5-hour exposure showed significantly less accumulation of dry matter than that under 16 hour, the optimum daylength. Finer graduation of daylength may settle the correct optimum. These results were in conformity with those reported by Redington (1929) who reported that *zea mays, Gossipium herbaceum, Pisum sativum* and *Linum usitatissimum* showed better growth with sixteen hours of light per day than continuous illumination which initiated early flowering. The observations of Adams (1925) that plants exposed to the longest action of light attained maximum production of dry matter did not find an unqualified support in these findings.

TABLE 1

Effect of Photoperiod on Dry Matter Accumulation in Gram

(Tops, gm. per plant)

Age (weeks)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	0·34	0·61	0·48	0·39
6	0·60	1·26	0·95	0·72
8	0·94	2·07	1·75	1·64
10	1·09	3·64	2·68	2·26
12	2·75	5·67	4·32	3·97
Mean	1·144	2·650	2·036	1·796

S. E. = 0·2168 C. D = 0·6680

The rate of increase in accumulation of dry matter advnced progressively with age in the 16 hour and 20-hour exposures but not in the control or the continuons light treatment (Fig. 1a).

Root weight was lessened by the extra hours of light exposures, significantly so, in the 16 and 20-hour sets though not in the 24-hour series; there was however, no significance in the difference among the various supra-normal exposure, (Table 2).

TABLE 2

Influence of Photoperiod on Dry Matter Accumulation in Gram.

(Roots, gm. per plant.)

Age (weeks)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	1·12	0·96	0·98	1·00
6	1·38	1·25	1·28	1·32
8	1·50	1·40	1·40	1·46
10	1·57	1·47	1·42	1·47
12	2·00	1·49	1·52	1·58
Mean	1·514	1·314	1·320	1·368

S. E. = 0·3873 C. D. = 1·1933

The rate of increase, between two observations, in root weight decreased with age in the 16-hour set while in the rest of the treatments increases were noticed during the period corresponding to 10—12 weeks of age (Fig. 1*b*). Maximum effect in the increase of dry matter accumulation was evident in the 16-hour photic stimulation for shoot and the normal exposure in the case of root during the second fortnight.

Shoot-Root Ratio

Top-root ratio increased significantly with increase in light duration (Table 3). Sixteen hour daily light supply produced maximum ratio that fell, in succession, with 20, 24 and 11·5-hour rations of light duration. While supra-normal light supply showed significant increase over control, no significant differences were noticed among these.

TABLE 3

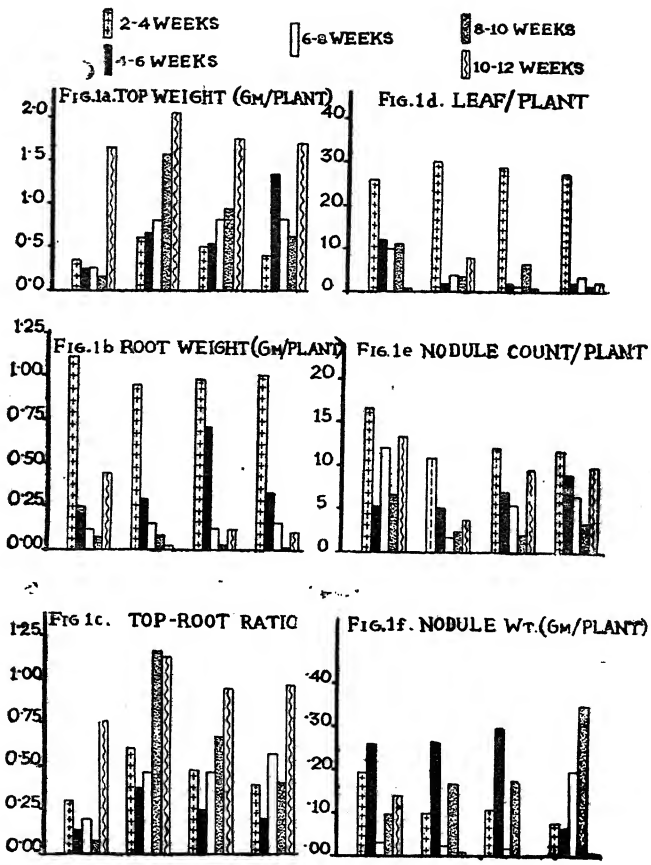
Influence of Photoperiod on Top/Root Ratio in Gram

(Dry weight basis)

Age (weeks)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	0·303	0·635	0·489	0·390
6	0·434	1·008	0·742	0·545
8	0·626	1·478	1·215	1·123
10	0·694	2·656	1·887	1·537
12	1·375	3.805	2·843	2·512
Mean	0·6464	1·9164	1·4352	1 2214

S, E. = 0·1700 C. D. = 0·5238

The bi-weekly increase in top-root ratio was maximum in the 16 hour light ration for practically throughout the age of the plant as against other exposures except 24-hour exposure between 6-8 week-age which effected largest increase (Fig. 1c).



Fortnightly Increase in certain Plant Attributes through the ontogeny of *Cicer arietinum* Plant

Leaf number

Largest number of leaves appeared on plants receiving normal light quantum, with increase in light du ation leaf number declined significantly and progressively (Table 4); 20 and 24-hour exposure plants showed wide fluctuations between themselves.

TABLE 4

Effect of Photoperiod on the Number of Leaves in Gram

(Leaf number per plant)

Age (weeks)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	25·7	30·4	28·7	27·4
6	37·7	32·7	30 7	29·6
8	47·4	36·5	32·2	33·2
10	58·6	40·4	38·7	34·5
12	58·4	48·5	39·2	36·4
Mean	41·42	37·70	33·90	32·22

S. E. = 2·276 C D. = 7·0126

The rate of increase in the number of leaves also remained highest in the 16-hour period in the 2-4 week age after which the rate declined to stand next to the normal exposure till the 8-10 week stage to be followed by a steep decline (Fig. 1*d*).

NODULATION

Nodular Infection

Numerical count of nodules, a measure of nodular infection, got less, significantly, with increase in light ration (Table 5). The optimum light treatment for dry matter accumulation in tops produced the least number of nodules. Beyond this i.e. in 20-hour and 24-hour illumination nodule count increased significantly, thus conditions bringing about a decrease in top-root ratio increased nodular infection. But for 20 and 24-hour photic treatments, that failed to show significant effect, all other exposures produced significant response among themselves.

TABLE 5

Influence of Daylength on Nodulation

(Nodule count per plant)

Age (week)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	16·6	11·0	12·1	11·8
6	22·3	16·2	19·2	20·8
8	34·2	18·0	24·4	27·4
10	40·5	20·4	26·5	30·6
12	53·8	24·2	36·4	40·5
Mean	33·48	17·96	25·72	26·22

S. E. = 1·895 C. D. = 5·8387

Nodule count, after the first fifteen days of exposure, stood at 16·6, 12·1, 11·8 and 11·0 in the normal, 20, 24 and 16-hour period respectively. In the next fifteen days the respective increases were 5·7, 5·2, 9·0 and 5·2 showing the marked effect of the continuous light treatment in increasing nodular infection. Later the normal exposure showed maximum increase of 11·9 which experienced a lowering in the 8-10 week age (6·3). The change of the floral primordium to a floral one accompanied by a marked accumulation of carbohydrate and protein in the stem tip (Biddulph, 1935) might be the controlling factor in reducing nodulation rate at that time. It was again raised to an increase of 13·3 in the 10-12 week age, the maximum increase for any 15-day period due to any treatment except its own in the 2-4 week stage (Fig. 1e). The sixteen hour daily light feeding brought forth minimum increase in nodule count than other treatments, age for age.

Nodular Development

While the infection of the root hair was affected significantly by a change in daylength, the subsequent development of nodules, as indicated by change in nodular mass, remained insignificantly affected by different light durations (Table 6) The trend of the results showed that 12-hour normal daylength was optimum followed by 20, 16 and 24 hour exposures in succession.

TABLE 6

Influence of Daylength on Nodular Development

(Gm., oven dry weight of nodules per plant)

Age (week)	Normal (11·5 hours)	16 hours	20 hours	24 hours
	D A Y L E N G T H			
4	0·192	0·100	0·110	0·081
6	0·452	0·369	0·410	0·150
8	0·483	0·396	0·431	0·350
10	0·581	0·565	0·615	0·702
12	0·722	0·574	0·615	0·702
Mean	0·4860	0·4008	0·4114	0·3590

Treatment not significant.

Maximum changes were introduced by normal daylength in the first and the last 15-day periods of observation. The increase observed in the 16, 20 and 24 hour period at the 10-12 week age was almost negligible while that in the normal daylength was substantial (Fig. 1*f*)

Flower Initiation

Daily period of light exposure had a profound influence on initiation of flowering in plants. Plants receiving normal light flowered 67 days after germination, while the 16, 20 24-hour illuminated lots took 47, 44 and 38 days respectively.

TABLE 7

Initiation of Flowering Under Different Treatments

Light treatments (duration)	Number of days taken for first bloom	Acceleration over the control
Normal ...	67	...
16 hours ...	47	20
20 hours ...	44	23
24 hours ...	38	29

Thus flower initiation was negatively and significently correlated with daily period of light exposure, Acceleration in initiation of flowering resulted from increase of the length of day in the supra-normal series; as against the control, speeding up was observed by 20, 23 and 29 days in the three increasing light exposures. *Cicer arietinum* was, thus capable of flowering over a range including normal long day illumination. The optimum for flower initiation was different from that for dry matter production posibly because flowering stimulus is a foliar influence entirely distinct from carbohydrate synthesis.

DISCUSSION

Cicer may be classed among long day-indeterminate group of plants, as it flowered in all illuminations from normal to continuous, combining the views of Kallerman (1926) and Allard and Garner (1940). Since the symbiotic relationship between leguminous plant and nodule bacteria was known to be affected by the carbohydrate content of the plants, it was postulated that a more active development of nodules may occur on the roots of the legume grown under long day than in short day. The effect of duration of the dark and light periods, on nodulation in gram, showed that with increase in light exposure beyond 12 hours, the numerical value of nodules declined significantly and for nodular mass the 11·5 hour daylength proved optimum. Infection of the root hair, as judged by nodule number was affected adversely and significantly by an increase in daylength; the daily light exposure that proved conducive to vegetative growth for longer duration of 67 days proved the optinum for noduble count (infection) as well as nodoule weight (development). The daylength conducive to dry matter accumulation or increase in shoot root ratio proved deleterious to nodulation, in gram as also reported earlier, (Singh, 1957) Kellerman's observations (1926) that in no case the light period best adapted for root growth coincided with the best daylight period for the upward or top growth of the particular plant under consideration seemed to be supported by these findings.

Optimum light exposure for leaf count proved best for nodulation though not for maximum dry weight. This signified that only the number of leaf, the seat of photosynthetic activity, did not necessarily control dry weight of the plants; carbohydrate manufactured being possibly utilised by the normally functioning bacteria present in the nodules of plants receiving normal illumination. The findings of Deats (1925) that the cell sap concentration in the leaves was higher in plants exposed to long day and the general contention that such exposure was asso-

ciated with increased content of reducing sugar in tops might be held responsible for greater dry matter production under 16 hours illumination but less nodule count and nodule weight as compared to the control.

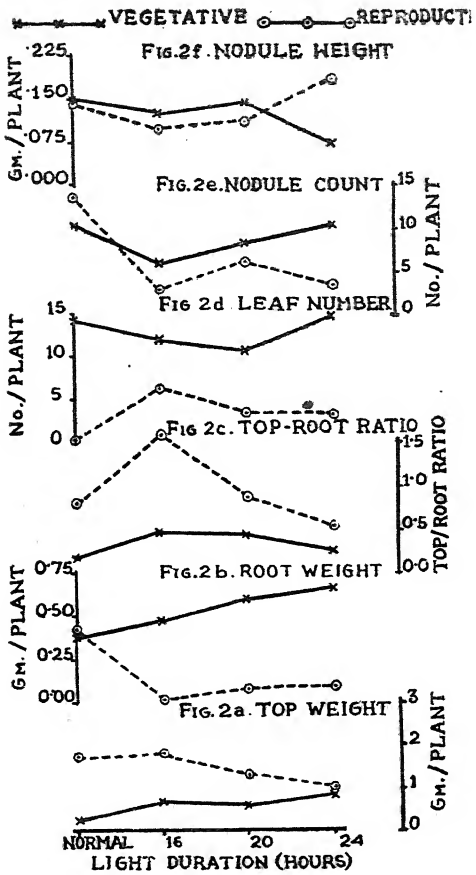
Garner and associates, in their several publications, indicated that a short day plant did not grow properly under conditions of long day and *vice versa*; increase in light exposure had an important bearing on the process of photosynthesis, though it could not be taken for granted that any additnon of light supply would be beneficial to each and every plant, especially in the supply of free carbohydrates to the roots. This seemed to the true in the case of *Cicer* though a long day plant.

Nodular infection and nodule development responded independently to photic stimulation, alteration in daylength could control root susceptibility to infection by the *Rhizobia* but failed to activate the bacteria lying in the nodular mass. The production of fibrous root system under long day conditions, as observed in dahlia by Zimmerman and Hitchcock, (1929) may be the reason of increase in root infection leading to more nodules. The ability of the bacteria to divide and multiply in the host as, judged by nodular mass, were apparently lost by increase in daylength. With increase in the carbohydrates in the supra-normal light exposures of 16-hours the C/N ratio was widened and the stimulation to growth increased leading to higher dry matter accumulation. The effect of photoperiod seemed to be directly on the host plant rather than the bacteria, findings similar to those reported by the author with *Phaseolus radiatus* (Type 1) with respect to contribution of minerals to nodulation (Singh, 1958). Arrested development by entombment and starvation and misuse of available carbohydrates in increased shoot growth might be the contributory causal factor indirectly at work in the inhibited development of nodules.

Investigating the problem more or less on similar lines as this, Cailahjan (1945) reported that the mass of root nodules was more intense in long day conditions in both short day as well as long day plants. Under the conditions of the present investigations light beyond 12-hours proved definitely detrimental for the development of nodules, possibly because tropical and sub-tropical plants were more sensitive to photoperiodic stimulation than the plants of more northernly latitudes.

Longer daylengths increased shoot-root balance but decreased leaf number and nodules production as against the control. This suggested that there existed a limit of daylength below and beyond which plant growth was not normal as also reported by Singh *et al* (1938).

Eaton (1931) observed, with soybeans, that the amount of growth and nodular development was in direct proportion to the length of day. He obtained different results under the same period of daylength when exposed in two different seasons, possibly due to marked differences in the intensity and quality of light which differed form season to season. The changeover from the vegetative to the reproductive phase, in *Cicer* rather than daylength, seemed to control nodulation. In the case of nodules the stage of development of the plant seemed to be the operative factor *viz.* maximum period taken in the initiation of flowering under the 12-hour period produced maximum nodular mass. Thus the greater the length of vegetative period greater was the weight of nodules. In case of nodular infection this factor did not seem to be operative when extra hours of light proved beneficial. In case of *Phaseolus radiatus* also it was observed that the changeover from the vegetative to the reproductive phase proved to be the controlling factor, on the contribution of minerals, to nodulation (Singh, 1958).



Fortnightly average rate of increase of plant attributes in *Cicer arietinum* separately for vegetative and reproductive phases under different daylengths

The bi-weekly effect of photic stimulations in the ontogeny of the plant depicted that the rate of increase of the various plant attributes did not have any particular trend either with age or the photo treatment (Fig. 2). All the same, in general, the results depicted that the effectiveness of the photic stimulus increased as the plant approached and attained the reproductive phase in all the treatments in respect of growth of tops (Fig. 2a). The difference in response narrowed as the light dose (duration) increased. In the growth rate of roots, the responses were just the reverse in that the increase in daylength widened the effect and the vegetative phase experienced larger growth rate (Fig. 2b). Reproductive stage of the plant showed higher rate of increase in every 15—day observation period in the top-root ratio; the 16 hour light treatment produced maximum effects (Fig. 2c). In leaf count, vegetative phase depicted higher increases irrespective of light treatments and the difference in the increase was maximum with normal light followed by 24-hour, 20-hour and 16-hour treatments in succession (Fig. 2d). In respect of nodular infection (nodule count) and nodular development the phase of the plant showed different trend (*cf.* Figs. 2c, 2f). Supra-normal photic stimulations increased progressively the rate of nodular infection in the vegetative phase (Fig. 2e). The bi-weekly

average of the rate of increase of nodular development remained higher in the vegetative period under 12, 16 and 20 hours of light feeding (Fig. 2f). The continuous light dose showed a sudden increased rate in the reproductive phase and a decrease in the vegetative period.

With respect to the rate of increase in other plant attributes only rarely photic stimulation showed a trend similar at both the vegetative and reproductive phases of *Cicer arietinum*. It was evident that the stage of growth and that of development did have a major influence on plant characters and that certain attributes *viz.* top growth rate and top-root ratio showed larger increase only in the reproductive phase irrespective of treatments signifyng the superiority of the developmental phase. In the rate of root growth and leaf number the vegetative held the dominating influence irrespective of daylength. Daylength beyond 20 hours proved more responsive in the increase of rate of nodular development, while the normal light duration was the best for increase in the nodular infection rate in the beginning as well as throughout the life cycle (Table 5). The controlling influence of the light duration lay in the initial effect in the first fortnight of exposure so that the normal daylength brought forth greater mass of nodules than the continuous light although the total increase between 4-12 week stage was greater in the latter case. It may, thus, be concluded that although daylength influenced the plant the influences were only subordinate to the plants' stage of development with respect to sexual maturity.

On the basis of overall absolute values normal daylength proved optimum for root weight, leaf number and nodule characters while the 16-hour exposure increased top weight and top-root ratio to the maximum (Tables 1-6). Taking the bi-weekly average of the rate of growth separately for the vegetative period under the illumination of 24-hours was responsible for maximum increases in top weight, root weight, leaf number and nodule number, while the normal and 16-hour light exposures produced maximum response with nodule weight and top-root ratio respectively. With the onset of the reproductive phase larger increases were noticed under the 16-hour treatment in respect of top weight, leaf number and top-root ratio whereas normal daylength increased root weight and nodule infection to the maximum and the continuous light was optimum for the increase in nodular mass. Thus the overall maximum response of daily light duration was largely similar to the treatment effect during the reproductive phase of the plant specially in the case of dry matter accumulation of top and root, their ratio and nodule count. Fortnightly increase in the dry weight of the nodules was maximum under the normal daylength whether considered on the basis of the entire life period or only the vegetative phase.

SUMMARY

Gram, *Cicer arietinum*, was grown under relatively controlled pot culture conditions and exposed to different photoperiod from normal to a prolonged 24-hour illumination to study the relation between length of day and nodular growth.

Normal daylength proved optimum for root growth, leaf number, nodule infection and nodular development. 16-hour day increased top growth top-root ratio to the maximum.

The importance of daylength as a great contributing factor of growth and of developmental activities was shown; not only the vegetative growth but also the time of flowering was affected profoundly. Increase in daylength was related to initiation of flowering directly; the 16, 20 and 24-hour photic exposures initiated flowering

earlier by 20, 23 and 29 days as against the normal daylength. Any exposure beyond the normal daylength was the reproductive photoperiod for *Cicer arietinum* which has been classed as long day indeterminate plant.

The controlling influence of the stage of development of plants on nodulation was shown to be the major one; the effect of daylength seemed to be only subordinate.

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OCCURRANCE OF TWO SPECIES OF THE CESTODE, *OOCHORISTICA* LUHE, 1898 IN A SOUTH INDIAN LIZARD

By

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Read at the 27th Annual Session of the Academy held at the University of Jabalpur on 27th December, 1957

While on a visit to South India, the author obtained three specimens of cestodes from the intestine of the common garden lizard, *Calotes versicolour* Daudin caught in the vicinity of Mandapam. In so far as the author has been able to determine, there are no previous records of cestodes from the garden lizard in this region. A single specimen is described here as new and two specimens represent a reported species.

OOCHORISTICA MANDAPAMENSIS N. SP.

Length of the specimen 14 mm.; maximum width of the strobila 0·53 mm. attained near the posterior end of the strobila. Scolex small, 0·16 mm. in diameter; passes insensibly into the neck region. Neck about 5 mm. in length. Suckers almost spherical with an average diameter of 0·09 mm. Segments all broader than long. Genital pores alternate irregularly and are situated at about the anterior third of the lateral margin of the segments. Genital cloaca large and muscular, 0·07 mm. deep with an average width of 0·03 mm. Dorsal and ventral longitudinal excretory vessels measure 0·009 mm. and 0·013 mm. in diameter respectively. Cirrus sac measuring 0·11 mm. × 0 03 mm. beyond the poral excretory vessels. Vas deferens almost straight with one or two coils in some segments. Cirrus and ductus ejaculatorius greatly coiled within cirrus sac. Testes 30-34 measuring 0·014-0·02 mm. in diameter. They occur in two lateral groups behind the ovary extending a little beyond the longitudinal excretory vessels. Ovary almost in the centre of the segment measuring 0·132 mm. across. Vagina is a thin tube posterior to the cirrus sac. Vitelline gland is irregular in shape, located behind the ovary and the vitelline gland and measures 0·035 mm. in width. No gravid segments were present.

Two species of *Oochoristica* have been reported from the garden lizard, *Calotes versicolour* from Lucknow; *O. thapari* Johri, 1934 and *O. indica* Misra, 1945. The present form from the same host in South India differs widely from both the species. Since Hughes (1940) who listed and gave a key to 45 species occurring in the genus by that time, a number of species have been added. The present form closely approaches *O. erinacei* Meggitt, 1920; *O. pennsylvanica* Chandler and Melvin, 1951 and *O. theileri* Fuhrmann, 1924. It is, however, distinguished from *O. erinacei* which is reported from a mammal in the arrangement of the testes. *O. pennsylvanica* which is also reported from a mammal is characterised by a longer strobila, larger scolex and suckers together with differences in the size and extent of the cirrus sac and, therefore, stands apart from the present form. *O. theileri* which closely resembles the present form in the size and extent of the cirrus sac and the arrangement of the testes in two groups, is easily separated by the limit of the testes within the longitudinal excretory vessels, presence of a receptaculum seminis and by a much shorter specimen (4-8 mm.) carrying larger scolex and suckers. The present form is, therefore, regarded to be a new species and named *Oochoristica mandapamensis* n. sp.

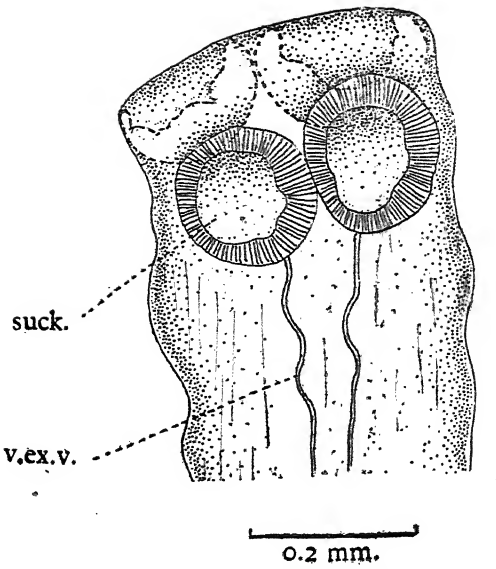

Fig. 1. Scolex of *Oochoristica mandapamensis* n. sp.

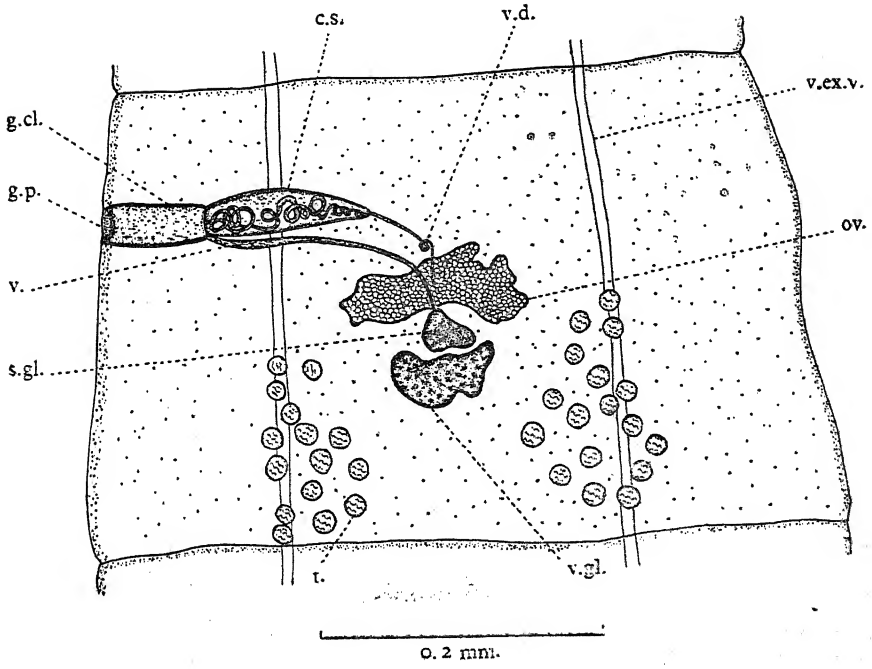

Fig. 2. Mature segment of *Oochoristica mandapamensis* n. sp.

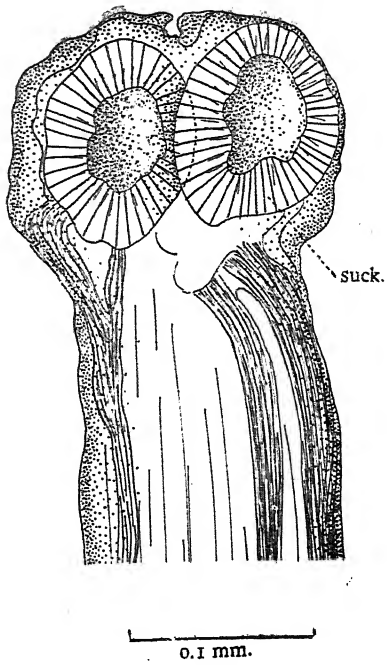

Fig. 3. Scolex of *Cochoristica lygosomatis* Skinker, 1935.

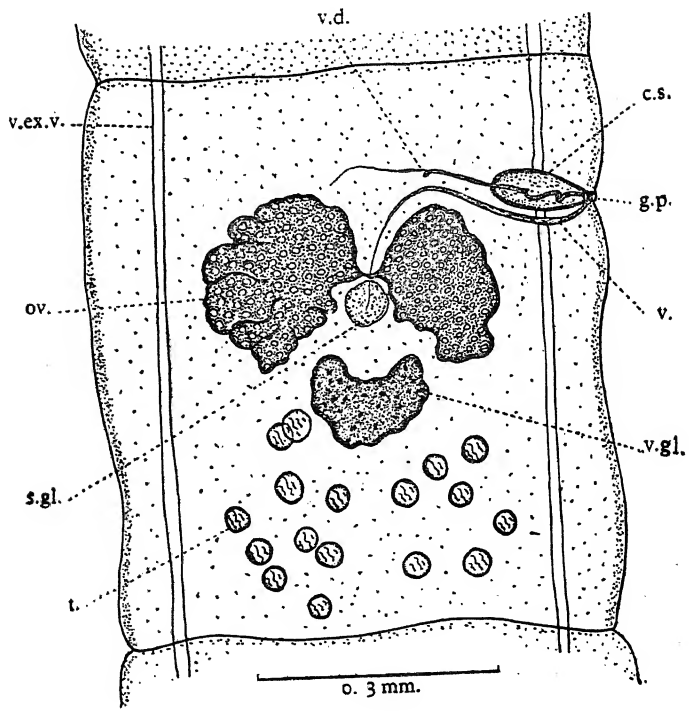

Fig. 4. Mature segment of *Oochoristica lygosomatis* Skinker, 1935.

c. s., cirrus sac; g.cl., genital cloaca; g. p., genital pore; ov., ovary; s. gl., shell gland; suck., sucker; t., testis; v., vagina; v. ex. v., ventral longitudinal excretory vessel; v. d., vas deferens; v. gl. vitelline gland.

OOCHORISTICA LYGOSOMATIS Skinker, 1935

This species was originally described as *Oochoristica parva* by Baylis (1929) from *Lygosoma chalcides* from Java. Subsequently, both Skinker (1935) and Baer (1935) independently found the specific name to be preoccupied with *Oochoristica parva* von Janicki, 1904 and hence named Baylis' material as *O. lygosomatis* n. comb. and *O. baylisi* n. comb. respectively. The differences found in the present form with the original material is mainly in the sizes of the strobila, scolex and suckers. A scolex and a mature segment are also drawn here since there were no diagrams of this species given in Baylis' paper.

Length of the specimens 34-52 mm., maximum width of the strobila 0·44 mm. Scolex globular, 0·152-0·190 mm. in diameter and well marked off from the neck. Suckers oval or round, 0·08-0·11 mm. in diameter. Genital pores alternate irregularly and are situated at about the anterior fourth of the lateral margin of the segment. Segments slightly longer than broad. Dorsal and ventral longitudinal excretory vessels measure 0·011 mm. and 0·020 mm. in diameter respectively. Cirrus sac measuring 0·12 mm. × 0·05 mm. beyond poral ventral longitudinal excretory vessels and about one fifth across the segment. Vas deferens simple. Testes 16-19 measuring 0·03 mm. in average diameter and situated behind the ovary and the vitelline gland. Ovary distinctly bilobed connected by a very narrow isthmus. Vagina posterior to the cirrus sac. Receptaculum seminis absent. Vitelline gland large, crescent shaped situated behind the ovary and measuring 0·14 mm. in diameter. Shell gland mass small, 0·04 mm. in diameter situated between the ovary and the vitelline gland. Eggs and onchospheres measure 0·045 mm. and 0·030 mm. in diameter respectively. Embryonic hooks measure 0·010 mm. in length.

The author is deeply indebted to Prof. M. B. Lal under whose guidance the present investigations were carried out.

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STUDIES ON THREE NEW SPECIES OF THE GENUS *Astiotrema* (TREMATODA : PLAGIORCHIIDAE) FROM FRESH WATER TORTOISES

By

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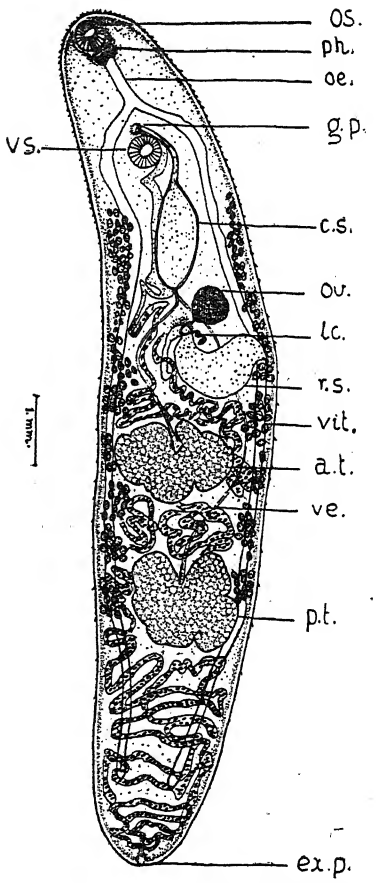
INTRODUCTION

In this paper three new species of the genus *Astiotrema* viz., *A. giganticum*, n.sp.; *A. lobiorchis*, n.sp. and *A. mehrai*, n.sp. have been described. These trematodes were obtained from the intestine of fresh water tortoises in April 1957.

The work was carried out in the Department of Zoology College of Science, Raipur.

ASTIOTREMA GIGANTICUM, n.sp.



Text Fig. 1. *Astiotrema giganticum*, n. sp. Ventral view.

A large number of these trematodes were obtained from the intestine of *Trionyx gangeticus*. The worms are dorsoventrally flattened with rounded anterior and posterior ends. measuring 10·0-12·5 mm. in length and 2·35-2·96 mm. in maximum breadth in the region of the anterior testis. The body is studded with small spines which are more closely arranged in the anterior half and become sparse posteriorly.

The oral sucker is subterminal in position and measures 0·37-0·47 mm. in diameter. The ventral sucker is larger than the oral sucker measuring 0·44-0·50 mm. in diameter and is placed at a distance of 1·33-1·93 mm. from the anterior end. The prepharynx is very small. The pharynx measures 0·09-0·23 × 0·28-0·30 mm. The oesophagus is 0·35-0·70 mm. in length and 0·07-0·19 mm. in breadth. The intestinal bifurcation lies at a distance of 0·91-1·90 mm. from the anterior end. The intestinal caeca terminate slightly infront of the posterior end of the body and have slightly crenated outermargins near the intestinal bifurcation.

The excretory pore lies at the posterior end of the body and leads into a Y shaped bladder. the median stem of which extends beyond the anterior testis.

The two testes lie in the posterior half of the body placed one behind the other between the intestinal caeca. The anterior testis measures 0·76-1·14 mm. in length and 1·52-1·78 mm. in breadth. The posterior testis measures 1·02-1·33 mm. in length and 1·52-1·82 mm. in breadth and is placed at a distance of 0·76-1·12 mm. from the posterior margin of anterior testis. Both the testes are lobulated having 6-7 obes with a deep notch infront, from where arise the vasa efferentia. The vasa efferentia join to from a small vas deferens at the base of the cirrus sac. The vas efferens from the posterior testis lies on the left and that from the anterior testis on the right side of the median line.

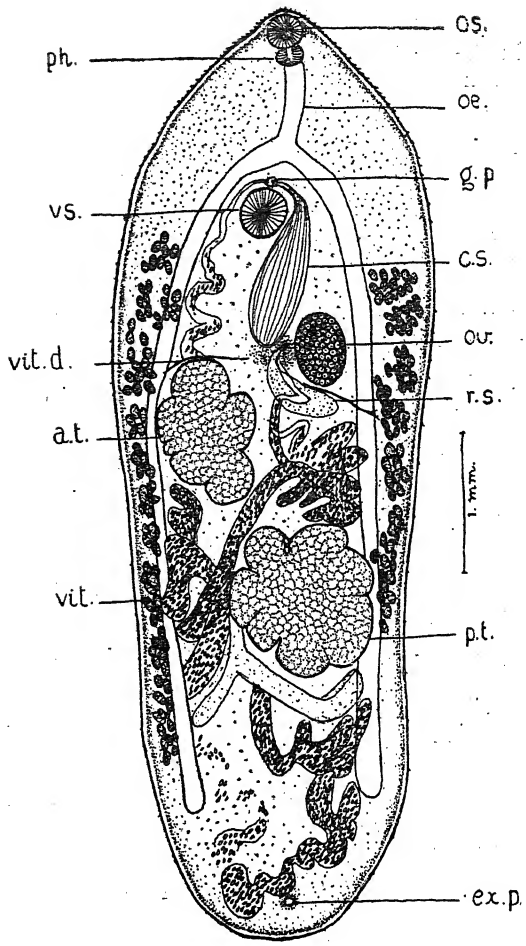
The cirrus sac is a large sac extending far beyond the acetabulum as far as the ovary. It is broad oval in its basal part and becomes tubular terminally. It is 1·50-2·28 mm. in length and 0·63-0·74 mm. in breadth. The vesicula seminalis occupies the basal part and the parsprostatica and the cirrus occupy the terminal part of the cirrus sac. The genital pore is situated just above the ventral sucker slightly to the right of the median line.

The subspherical ovary is situated on the left side close to the left intestinal caecum at a distance of 2·96-4·18 mm. from the anterior end and measures 0·46-0·57 mm. in length and 0·51-0·56 mm. in breadth. From its postero-lateral aspect arises the oviduct which after a short course receives the duct of the receptaculum seminis and the laurer's canal. The octype is situated on the right side of the ovary in the median line. The receptaculum seminis is a large sac, semilunar in shape located betwen the ovary and the anterior testis. The receptaculum seminis is transversely disposed and measures 0·98-1·19 mm. in length and 0·68-0·77 mm. in breadth.

The vitelline follicles are arranged in groups along the two sides of the body. They extend from the level of the neck of the cirrus sac to the level of the middle region of the posterior testis. The lateral vitelline ducts anterior and posterior lead into transverse ducts behind the posterior margin of the ovary.

The uterus arises from the right side of the ootype. Its descending and ascending coils pass between the two testes and extend upto the posterior end of the body. The metraterm runs along the cirrus sac and opens into the genital artium.

The eggs are oval in shape and measure 0·03-0·036mm. in length and 0·015-0·018mm. in breadth.



Text Fig. 2. *Astiotrema lobiorchis* n. sp. Dorsal view.

The description of *Astiotrema lobiorchis*, n. sp. is based on a single specimen obtained from the intestine of *Kachuga dhongoka* from a local tank. The worm is dorsoventrally flattened with rounded anterior and posterior ends. It measures 6·6 mm in length and 2·3 mm. in breadth in the region of the anterior testis. The body is beset with numerous small spines in the anterior region.

The subterminal oral sucker measures 0·22 × 0·25 mm. The ventral sucker is larger than the oral sucker and measures 0·35 mm. in diameter and is situated at a distance of 1·26 mm. from the anterior end. The pharynx measures 0·13 × 0·16mm. It is preceded by a small prepharynx measuring 0·06 × 0·11 mm. The oesophagus is 0·56 mm. in length and 0·21 mm. in breadth. The intestinal bifurcation lies at a distance of 0·98 mm. from the anterior end. The intestinal caeca run along the sides of the body and terminate about half way between the posterior margin of the posterior testis and the hinder end of the worm.

The excretory pore is situated at a distance of 0·22 mm. from the posterior end and leads into a Y shaped bladder.

The two testes are diagonally placed in the middle third of the body. The anterior testis which touches the left intestinal caecum measures 1·05 × 0·85 mm. and is 2·6 mm. away from the anterior end. The posterior testis 1·12 × 1·05 mm. in size touches the right intestinal caecum and is placed at a distance of 0·12 mm. from the anterior testis. Both the testes are lobulated having 6-7 lobes with a posterolateral lobe smaller than others.

The cirrus sac is large, oval, bag like extending behind the ventral, sucker upto the middle level of the ovary. It is broad in its basal part and narrow in its terminal part and measures 1·13 mm. in length and 0·36 mm. in breadth. It encloses the vesicula seminalis which fills up its greater part, a tubular parsprostatica surrounded by large number of prostate glands and a cirrus. The genital pore is just above the ventral sucker in the median line.

The ovary is placed close to the right intestinal caecum 2·2 mm. from the anterior end. It is oval in shape and measures 0·56 × 0·39 mm. From its median lateral aspect on the right side arises the oviduct which after a short course receives the duct of receptaculum seminis. The receptaculum seminis is a large sac transversely disposed measuring 0·84 × 0·17 mm. The ootype is on the right side of the ovary in the median line at the base of the cirrus sac.

The vitellaria are mostly extracaecal in position and extend anteriorly upto the posterior level of the ventral sucker. posteriorly they terminate a little infront of the intestinal caecum on the left side while on the right they extend to about 3/4th level of the posterior testis.

The uterus arises from the posterior side of the ootype. Its coils extend upto the posterior end of the body. The terminal part of the ascending limb extends close to the left intestinal caecum and opens into the genital atrium.

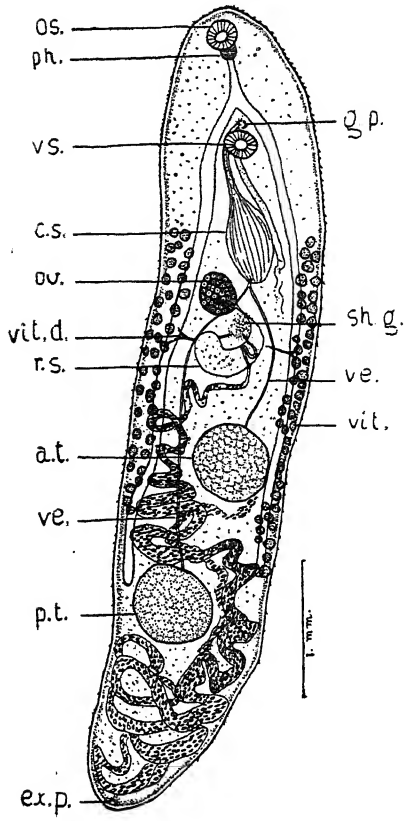
The uterine eggs are oval in shape and measure 0·03 × 0·012 mm.

ASTIOTREMA MEHRAI, n. sp.

A large number of specimens of this species were obtained from the intestine of *Kachuga dhongoka*. The worms are elongated with rounded anterior and posterior ends. They measure 5·7-6·9 mm. in length and 1·19-1·49 mm. in breadth at the level of the anterior testis. The body is beset with sharp pointed spines which are more crowded towards the anterior end.

The oral sucker measures 0·19-0·21 mm. × 0·19-0·21 mm. and is approximately equal to the ventral sucker. The ventral sucker 0·19-0·22 × 0·19-0·22 mm. in size is placed at a distance of 0·85-1·18 mm. from the anterior end. The prepharynx is very small. The pharynx measures 0·12-0·14 × 0·105-0·11 mm. The oesophagus is 0·28-0·56 mm. in length and 0·06-0·105 mm. in breadth. The intestinal bifurcation lies at a distance of 0·58-0 91 mm. from the anterior end. The posterior extension of intestinal caeca vary in different specimens from the anterior level of the posterior testis to the posterior level of the posterior testis. In some specimens the right intestinal caecum is larger than the left while in others the left is longer than the right one.

The excretory pore is terminal and leads into a Y shaped bladder. The two rounded testes are placed diagonally one behind the other in the posterior half of the body. The anterior testis is nearer to the left intestinal caecum and the posterior one to the right caecum. The anterior testis measures 0·56-0·63 × 0·56-0·72 mm. and is placed at a distance of 2·93-3·69 mm. from the anterior end. The



Text Fig. 3. *Astiotrema mehrai* n. sp. Ventral view.

posterior testis measures 0·56-0·7 × 0·5-0·67 mm. in size and is 0·39-0·7 mm. behind the anterior testis. The two vasaefferntia arise from the anterior aspect of the testes and unite to form a small vasdeferens at the base of the cirrus sac. The cirrus sac is long sac like with a tubular anterior part and extends to about the middle level of the ovary or ends a little infront of it. In size it measures 1·09-1·3 mm. in length and 0·29-0·35 mm. in breadth at the region of the sac. The vesicula seminalis occupies the basal part of the cirrus sac and a tubular parsprostatica surrounded by large number of prostate glands lies in the tubular neck like part of the cirrus sac. The genital pore is located above the ventral sucker in the median line inbetween the intestinal fork.

The ovary is situated on the left side close to the left intestinal caecum at a distance of 1·78-2·47 mm. from the anterior end. It measures 0·31-0·34 mm. × 0·25-0·31 mm. in size. The oviduct arising from the posterolateral aspect of the ovary after a short course receives a small duct from the receptaculum seminis. The receptaculum seminis is transversely placed and is a sac like structure measuring 0·63-0 70 mm. in length and 0·21-0·24 mm. in breadth.

The vitelline glands of the two sides extend to different levels anteriorly as well as posteriorly. The posterior extension of the vitellaria of the left side is always longer than that of the right side. Anteriorly the glands of both the sides extend to about the middle level of the cirrus sac, though in some specimens the level of extension is different on the two sides. The posterior extension of the vitellaria on the right side varies from the posterior level of the anterior testis to the anterior level of the posterior testis, while that of the left varies from midway between the two testes to the middle level of the posterior testis. The transverse vitelline ducts of the two sides unite to form a common duct above the receptaculum seminis.

The coils of the uterus pass between the two testes and continue upto the posterior end of the body. The terminal part of the ascending limb runs along the cirrus sac and opens into the genital atrium. The eggs are oval in shape and measure 0·024-0·027 mm. × 0·012-0·015 mm.

DISCUSSION

There are 21 species of the genus *Astiotrema* Looss, 1900 reported so far from different parts of the world. They are *Astiotrema reniferum* (Looss, 1898) Looss, 1900; *A. impletum* (Looss, 18 9) Looss, 1900; *A. monticellii* Stossich, 1904; *A. emydis* Ejsmont, 1930; *A. elongatum* Mehra, 1931 and *A. Loossii* Mehra, 1931; *A gangeticus* Harshey, 1932; *A spinosa* Chaterji, 1933; *A. indica* Thaphar, 1933; *A. rami* Bhalerao, 1936; *A. odhneri* (Odhner, 1911) Bhalerao, 1936; *A. orientale* Yamaguti, 1937; *A dassia* Dayal, 1938; *A. amydae* Ogata, 1938; *A fukuii* Ogata, 1938; *A. foochowensis* Tang, 1941; *A. nathi, A. matthai; A. hoshiarpurium, A. srivastavai* and *A. thapari* Gupta, 1954; *A. gangeticus* has been synonymized to *A. loossii* by Bhalarao, 1936. *A. amydae* and *A. foochowensis* have been synonymised to *A. orientale* by Gupta (1954).

A. giganticum n. sp. and *A. lobiorchis* n. sp. differ from all the known species of *Astiotrema* except *A. odhneri, A. loossii A. dassia* and *A. indica* in the possession of deeply lobed testes. They differ from *A. odhneri, A. dassia* and *A. indica* in relative size of suckers, shape of testes, and extension of vitellaria; and from *A. loossii* in size, extension of vitellaria shape of ovary and testes, and size of receptaculum seminis. They differ from each other in size, lobulation of testes, (in *A. giganticum* testes are deeply notched at their anterior faces) and in the extension of vitellaria and intestinal caeca.

A. mehrai n. sp. differs from all the known species of the genus except *A dassia, A. indica* and *A. thapari* in having both the suckers equal. It differs from them in the possession of rounded testes, extension of intestinal caeca and in the distribution of vitellaria.

The above differentiating characters lead to the creation of three new species of the genus *Astiotrema* viz. *Astiotrema giganticum*, n. sp ; *A. lobiorchis* n. sp. and *A. mehrai* n. sp.

ACKNOWLEDGMENTS

The author is grateful to Dr. R. N. Singh, Reader in Zoology College of Science, Raipur for his keen interest and guidance in this work. Thanks are also due to Principal U. D. Mukerjee College of Science, Raipur for providing necessary research facilities. I am thankful to Shri J. N. Saksena, Lecturer in Zoology, College of Science for help in many ways.

LETTERING

at	anterior testis	ph	Pharynx
C. S.	Cirrus sac	pt	Posterior testis
ex. p.	Excretory pore	rs	Receptaculum seminis
g. p.	Genital pore	sh. g.	Shell gland
l. c.	Laurer's Canal	Ve	Vas efferens
oe	Oesophagus	Vit.	Vitelline glands
O. S.	Oral sucker	Vit d.	Transverse vitelline duct.
OV	Ovary		

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PATHOLOGICAL STUDIES OF A STORAGE ROT OF APPLES CAUSED BY *ASPERGILLUS TERRUS* THOM.

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INTRODUCTION

Fruits play an important part in the diet of men. It is, therefore, necessary to grow them in large quantities and to save them from diseases which occur at various stages of their growth. They appear not only while the fruits are on the tree but may appear even after picking. Many fruits like apple 'NAKH', NASHPATI', banana, 'LOQUAT', peach, grape, etc., have to be carried to long distances from the centres of production. They may thus suffer serious losses during transit, storage and marketing because storage rots appear and may ruin the entire fruit. Such fruits not only fetch lower price but their keeping quality is greatly impaired which forces the dealers to dispose them off as early as possible.

The storage diseases of fruits caused by various fungi have been studied in different countries of the world but much work has not been done in India. The investigations of Brook and Fisher (1914), Horne and Horne (1920), Kidd and Beaumont (1924), Newton (1928), Huber (1930 and 1932), Simmonds and Mitchell (1940) and Rose *et al* (1950) have added much to our knowledge about such troubles. Cook (1950) has summarized the work done on transit, storage and market diseases of fruits and vegetables in U. S. A.

In our country the storage and transit diseases of pome fruits have been studied by Dastur (1916) who worked on storage rot of apple and pear, Dey and Nigam (1933) on soft rot of apples, Kheswala (1936) on fruit diseases in Baluchistan, Prasad (1938) on rot of pear, Mehta (1939) on *Rhizopus* rot of apple, Singh (1941) on a soft rot of apple caused by *Penicillium expansum*, Sinha (1947) on storage rot of fruits, Tandon and Tandon (1948) on *Pestalotia* rot of apples, Singh and Grewal (1953) on soft rot of pears, but the fruit rot of apples caused by *Aspergillus terreus* has not been reported so far. It was, therefore, decided to undertake the physiological and pathological studies of this fungus. The details of pathological studies have been included in the present paper.

MATERIAL AND METHOD

Aspergillus terreus Thom was invariably isolated from the diseased parts of certain rotten apples found in the local market. Single spore cultures were prepared by dilution method any they formed the parent cultures.

The method described by Granger and Horne (1924) was used for artificial inoculations. The fruits were also inoculated through injured and uninjured regions by placing the inoculum at calyx and stem ends or at other injured surfaces of the fruits which were subsequently wrapped in sterilized paper. Controls were maintained in each case. The method suggested by Tandon and Tandon (*l.c.*) was followed for studying the effect of different environmental conditions *e. g.*, temperature and light.

Ridgway's (1912) colour standard and nomenclature was used for determination of various colours. Other details are given at appropriate places in the text.

SYMPTOMS

In apples the disease started from any injured part on the surface of the fruit During the earlier stages the diseased spots were greenish yellow to dark yellow but they changed to Apricot-Buff and finally to Cinnamon-Rufous. As the age advanced the colour of the central region became darker *i.e.*, Haze or Hay's Russel, while the peripheral region remained lighter coloured *i.e.*, Apricot Buff or Cinnamon-Ruffous. The spot was surrounded by a very small region (2 m. m. in width) which was pale green yellow in colour but it was not distinct from a distance. The spot increased rapidly and within a week it attained a size of 45—55 m. m. The entire fruit was ultimately destroyed within 25—35 days. Such fruits could easily be recognized on account of unpleasant mouldy odour which was particularly pronounced when they were cut. The spots were clearly marked from the healthy portions of the fruit (vide figure No. 1). In certain cases shrinkage was also noticed in the centre of the spot. This was more marked in 'NASHPATI' and 'NAKH' where the rotten area appeared soft and watery.

The decayed flesh was brown, firm and moist although it appeared some-what dry. The rot extended inside in a conical shaped area and it spread much deeper inside the fruit than on its surface (vide fig. No. 3). The shape of decayed region was rectangular in 'NAKH' and 'NASHPATI'.

Pathogenicity : The fungus was inoculated by the various methods described before and it was observed that the fruits were readily infected from injured areas, as well as from the stem or calyx end without any injury. There was no infection from other uninjured areas. It is thus evident that the fungus could enter through the wounds or through the stem or calyx end. Similar results were obtained by Tandon and Tandon (*l.c.*) for *Pestalotia* rot of apples as well as by Singh (l. c.) who worked on a soft rot of apple caused by *Penicillium expansum*. Reisolations were made from the diseased areas and *Aspergillus terreus* was always isolated. The control fruits remained healthy.

Effect of Temperature : To study the effect of temperature on the incidence of the disease some healthy as well as inoculated fruits of equal size were kept at 7°c, 20°c and 30°c±2°c. The results are summarized in Table No. 1.

Table 1 :—Showing the diametric decay of apples caused by *Aspergillus terreus* at different temperatures on 18th day of inoculation :—

TABLE 1

Inoculations	Diametric decay in m.m.		
	7°c	20°c	30 c°±2°c
Apple No. 1	No decay	23 × 22	42 × 42
,, 2	,,	22 × 22	40 × 40
,, 3	,,	22 × 22	41 × 40
,, 4	,,	24 × 24	40 × 40
,, 5	,,	20 × 22	41 × 40
,, 6	,,	20 × 20	40 × 42
,, 7	,,	25 × 25	38 × 38
,, 8	,,	24 × 24	39 × 39
AVERAGE	,,	22·7	40·0
CONTROL	No decay	No decay	No decay

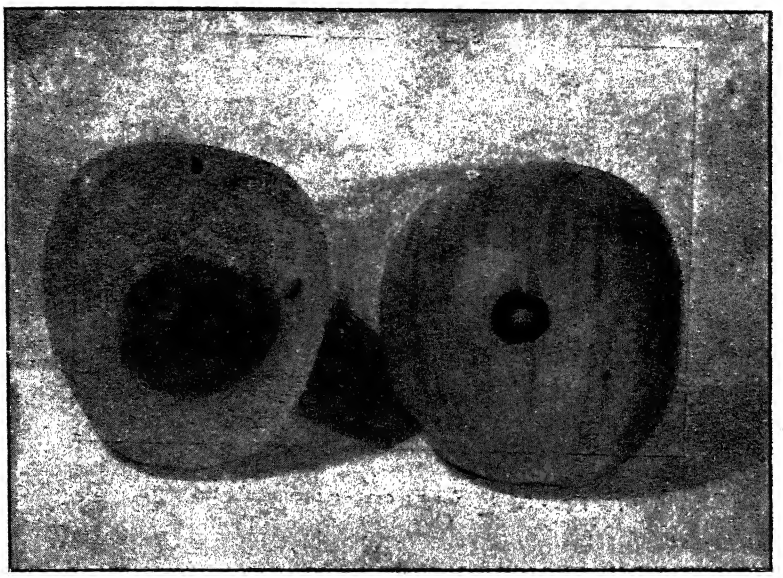

Fig. 1. Showing healthy and infected fruits of apples. (Left)—infected (Right)—healthy.

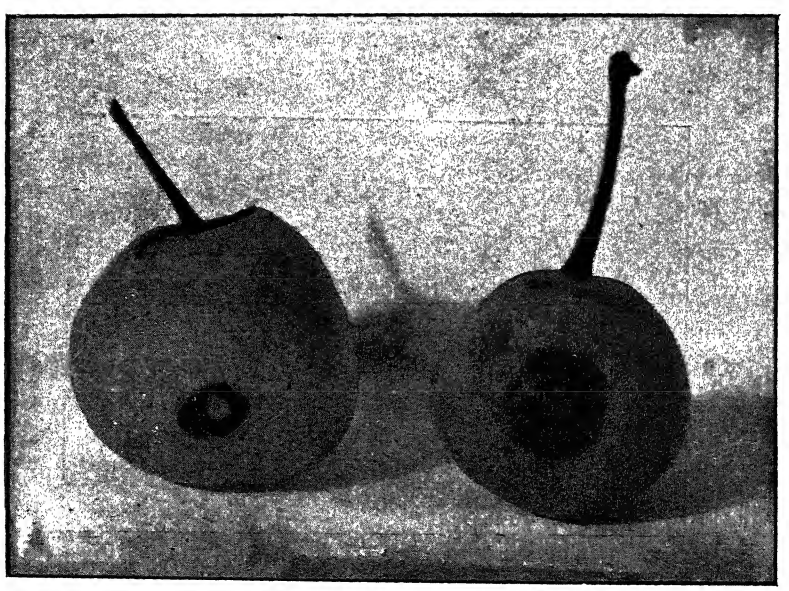

Fig. 2. Showing healthy and infected fruits of 'Nashpati' (left)—healthy (right)—infected.

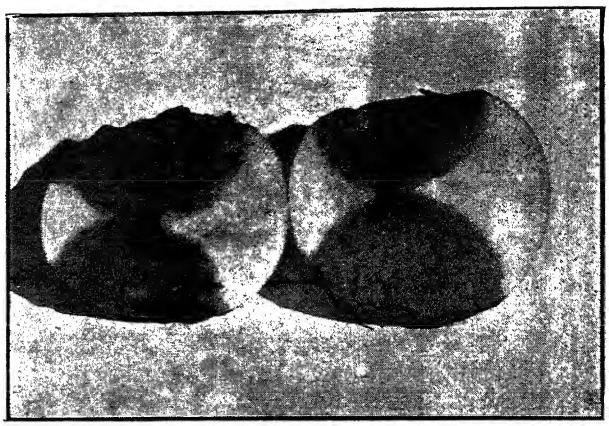

Fig. 3. Showing a cross-section of infected apple.

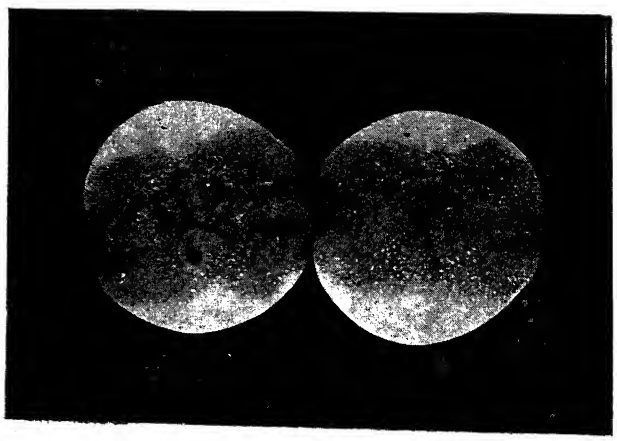

Fig. 4. Showing a cross-section of infected 'Nashpati'.

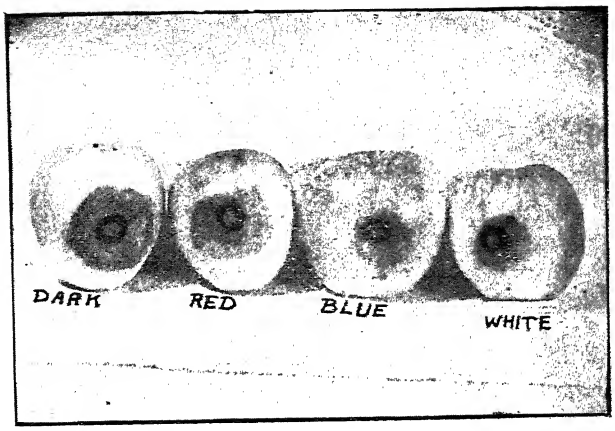

Fig. 5. Showing the effect of light of different types on the rot of apples.

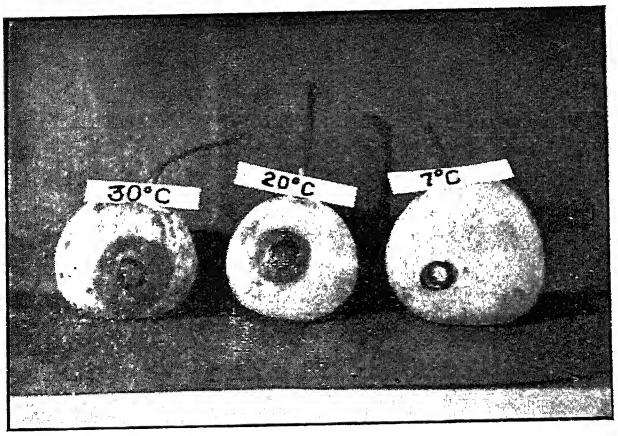

Fig. 6. Showing the effect of temperature on the decay of 'Nakh'.

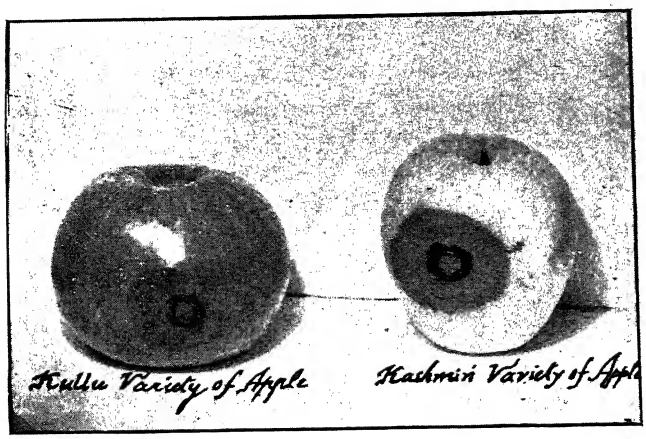

Fig. 7. Showing the amount of rot on two different varieties of apples.

It is clear from the above table that there was no rotting at 7°c but the infection increased gradually with an increase of temperature from 20°c to 30°c ±2°c. This rotten areas at 30°c ±2°c was about twice as large as at 20°c.

Effect of light : The physiological investigations had revealed that there was a pronounced effect of different types of light as well as darkness on the growth of *A. terreus*. It was, therefore, decided to find out the effect of darkness and light of different colours on the progress of the fruit rot. Fruits were stored in different lights *i.e.* red, blue, white, total darkness and intermittant light and darkness. The diametric decay under various conditions is recorded in Table II.

Table 2 :—Showing the decay of apple and 'NAKH' under different conditions of light, darkness as well as in intermittant light and darkness.

TABLE II

Different conditions	Decay in m. m.	
	Apple	Nakh
1. Darkness ...	52×52	56×56
2 Intermittant light and darkness. ...	41×40	45×44
3. Red. ...	38×37	41×40
4. Blue ...	33×33	36×35
5. White ...	30×30	33+32

It is evident from the above table that the maximum decay of the fruit took place in total darkness. This was followed by intermittant light and darkness and red light. The minimum rot was in continuous white light. The decay was also comparatively less in blue light but the difference between continuous white light and blue light was not significant. In general the disease was not controlled under any type of light and in this respect the results differed from those of Tandon and Tandon (*l.c.*) who reported that the rot of apples caused by *Pestalotia* was nearly controlled by red light.

Varietal trials :—Only two varieties (one acidic and the other sweet) viz., 'KULU SEV' and 'KASHMIRI SEV' were used for studying the effect of varietal differences on the pathogenicity of the fungus.

It was noticed that 'KASHMIRI' variety of apples were more susceptible than 'Kulu' variety. The damage to the latter was 31 % less than in the former. The physiological investigations had established that the growth of the organism was poor at pH 2 and it increased with the increase of pH upto 6. The poorer infection of 'Kulu' apple appears to be connected with higher acidity of those fruits.

Host range trials :—Inoculations were also made on 'Nakh' 'Nashpati' and guava. It was observed that 'Nakh' and 'Nashpati' were rotten but guavas were not attacked. The disease was more serious on 'Nashpati' than on 'Nakh' or apples and this clearly indicated that 'Nashpati' was more susceptible than the other

two fruits. The effect of temperature and lights of different types on 'Nakh' and 'Nashpati' was also studied and it was established that the results were exactly similar to those obtained with apples.

CONTROL

Previous experiments had indicated that the disease could be controlled by preventing injury to the fruits or by storage at low temperature (7°c). In view of the fact that during picking, washing and storage some injuries may become inevitable and infection may also be caused through stem or calyx end it was decided to wrap the fruits in sterilized paper after careful handling. It was found that in such cases the damage was negligible. The fruits were also exposed to vapours of carbon di-oxide for 60, 120 and 240 mts. In all such cases there was no decay in the exposed fruits. It is thus evident that injury should be avoided in order to control the disease and the fruits may either be stored at 7°c or should be exposed to CO_2 vapours.

SUMMARY

1. *Aspergillus terreus* Thom used in the present investigation was isolated from rotten apples in the local market. The symptoms of the disease have been described.
2. Infection took place through injury or through calyx or stem end of the fruits.
3. The effect of temperature and light on the advance of the rot was studied and the details have been recorded.
4. Inoculations showed that 'Nakh' and 'Nashpati' were also susceptible to the fungus while guava was not attached.
5. 'Kashmiri' variety of apple was found to be more susceptible than 'Kulu' variety.
6. Suggestions have been given for the control of the rot.

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EXTENT OF THE GILL-SURFACE IN THE TELEOSTS *HETEROPNEUSTES FOSSILIS* BLOCH AND *CLARIAS BATRACHUS* LINN.

By

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INTRODUCTION

Gills have their greatest development among the Teleostomi, and considering the respiratory area, they have been regarded as surpassing the lungs in efficiency. Gills are structures which increase the area and efficiency for gas transport across the respiratory surfaces. Among fishes there are obvious species differences in the number of branchial arches, in the number and length of the gill-filaments. Differences in number and size of the respiratory units, the gill-lamellae is less obvious. This points out that there is also variations in gill-surface area per unit weight and volume of the fish.

The gills of a number of tropical freshwater fishes show considerable modifications with changes in Oxygen environment, and frequently function in combination with other respiratory structures in the exchange of vital gases. These organs increase the efficiency or supplement the action of gills. Many of these adaptations permit air-breathing during deficiency of Oxygen dissolved in water or during temporary stay outside water, allowing some obviously aquatic teleosts to become temporary land dwellers. The fact that the accessory respiratory organs supplement the gills, indicates the inability of the gills in air-breathing fishes to absorb the full complement of the Oxygen required by the fish. In other words it means that their gills must be in some way deficient. That a size deficiency of gills exists in few of these species, *Anabas testudineus, Ophicephalus striatus* and is also reported in *Amphipnous cuchia* (Hora '35 & Das '40). To my knowledge this is the first record of the extent of gill-surface in these two fishes except that of *Heteropneustes fossilis* by Dubale ('51).

HISTORICAL

Although there have been some studies on the anatomy of fish gills, only a few investigators have concerned themselves with gill-area. Reiss (1881) was the first to attempt accurate measurements of the gill-surface. Putter (1909) determined gill-surface area of a few fishes, and observed that the respiratory surface was proportional to the body surface but not to body weight. The most extensive study of a single species was made by Price (1931). The study of a comparative nature appears to be that of Schottle (1931), who found a reduction of gill-surface in terrestrial gobiform fishes compared to strictly aquatic species and Gray (1954) studied the comparative gill-surface area in marine fishes. There is no available literature on the subject in India except on the degeneration of gills in the air-breathing fishes by George and Dubale (1941) and Dubale (1951) on a comparative study of the extent of the gill-surface in some representative Indian fishes, and tis bearing on the air-breathing habit.

MATERIAL and METHODS

The fishes were procurred in the living condition from the fish market and fisherman at Kanpur.

The method of Gray (1954) have been followed. To obtain the respiratory area of a fish it is necessary to know the total area of the lamellae. It is of course, impractical to measure each of the thousands of lamellae present ; consequently sampling method was employed.

After weighing the fish and ascertaining the volume by the displacement by immersion, the gill-arches of one side were dissected out, carefully separated, and placed in dishes of saline water, one arch to each dish. The gill-arches of the other side were dissected out and fixed. Fresh gills were compared with the fixed preparations of filaments and it was found that they tallied. The fixed preparations were better for the purpose of measuring and camera lucida drawings of the lamellae.

The number of filaments on each side of each arch was counted with the help of a stereoscopic binocular microscope. The length of the filaments was determined by measuring every third filament with the help of mechanical stage of the compound binocular microscope, keeping in view that length of different size filaments have been measured (as the filaments were not necessarily of uniform length). From these measurements the average length of the filaments was determined. By placing the filaments of approximately average length under the low power objective of a compound microscope and using a stage micrometer, the number of lamellae per millimeter of the filament was determined. Camera lucida drawings of several average size lamellae were made. Area by graph method of the lamellae was determined and an average taken.

Knowing the number of gill-filaments, the average length of the filaments, and the number of lamellae per millimeter of filament, the total number of gill-lamellae was calculated. From this and the known magnification and area of the camera lucida drawings, the total area of gill-surface was determined. The central cartilagenus support of the filament that runs through each lamella was not included in the determination of gill area. Since the lamellae are functional on both sides the calculated area was doubled.

Admittedly, with so many manipulations there is a large possibility of error in determining-gill area. However, all specimen were treated in the same manner so that the result ontained would be comparable.

RESULTS

Heteropneustes fossilis :—In Table I the weight and volume of the fish along with the number of the filaments, average length of the filaments, the number of gill-lamellae per millimeter of the filament, the area of a lamella, total gill-area, and gill-area per unit of weight and volume are given.

The average length of the filaments varied from 2·05 to 3·02 mm., the number of gill-filaments of one side varied from 304 to 368, the lamellae per millimeter of the filament varied from 14 to 26, and the total respiratory area varied from 9356 to 16680 sq. mm.

TABLE I

GILL AREA OF *HETEROPNEUSTES FOSSILIS*

Number.	Weight (gms.)	Volume (C. C.)	Total no. of filaments of one side	Average length of filament (mm.)	Lamellae per m.m. of the filament	Area of lamella (Sq. mm.)	Total respiratory area (Sq. mm.)	Gill-area (Sq. mm.) Per gram of body weight	Gill-area (Sq. mm.) Per c.c. of body volume
1	28·00	24·0	168 × 2	2·44	19	·15	9356	434·1	389·4
2	23·55	20·0	164 × 2	2·23	17	·20	9745	413·8	487·3
3	29·70	25·3	167 × 2	2·05	26	·19	13770	457·8	544·3
4	34·60	30·4	152 × 2	2·18	22	·17	10030	289·8	329·9
5	33·65	32·0	179 × 2	2·12	23	·22	15010	446·2	469·1
6	45·25	44·0	170 × 2	2·33	24	·16	12910	285·4	293·5
7	31·00	29·0	185 × 2	2·28	20	·25	16680	538·1	575·3
8	37·90	35·0	184 × 2	2·16	23	·21	15720	414·9	449·1
9	41·90	38·0	174 × 2	2·35	18	·26	15510	365·5	402·9
10	54·00	50·0	193 × 2	2·86	14	20	12454	230·7	249·9
11	71·10	68·0	177 × 2	3·02	15	·20	12945	182·1	190·4

Clarias batrachus:—In Table II the weight and volume of the fish along with the number of filaments, average length of the filament, the number of gill-lamellae per millimeter of the filament, the area of a lamella, total gill-area, and gill-area per unit of weight and volume of *Clarias* are given.

TABLE II

GILL AREA OF *CLARIAS BATRACHUS*

Number	Weight	Volume c.c.	Total no. of filament of one side	Average length of filament	Lamellae per mm. of the filament	Area of Lamella (Sq. mm.)	Total respiratory area (Sq. mm.)	Gill-area (Sq. mm.) Per gram of body weight	Gill-area (Sq. mm.) Per c.c. of body volume
1	60·5	58	491	2·65	19	·15	15180	250·8	261·7
2	66·65	60	437	2·89	18	·14	12730	191·0	212·1
3	36·7	32	477	2·51	21	·12	12070	329·0	377·3
4	40	30	443	2·63	20	·16	14910	372·7	497·1
5	35·7	34	474	2·40	21	·16	15290	428·2	450·6
6	54	50	451	2·78	18	·15	13540	250·7	270·8
7	61·5	60	476	2·92	18	·17	17010	276·6	283·4
8	55	54	459	3·00	19	·12	12560	228·3	232·6
9	58	54	435	2·84	19	·20	18780	323·8	347·7
10	46·7	44	441	2·46	18	·18	14060	301·0	319·5

The number of gill-filaments on one side varied from 435 to 499, the average length of the filament varied from 2·4 to 3 mm., the lamellae per millimeter of the filament varied from 18 to 21, and the total gill area varied from 12070 to 18780 sq. mm.

DISCUSSION

A large number of small lamellae means more surface than a small number of large lamellae. But other factors such as the length of the filaments, the number of filaments and the number of gill-arches are also important in determining the amount of the gill-surface. The number of lamellae per millimeter of gill-filament as reported (Gray 1954) in *Scomber scombrus* is 31, *Scomberomorus maculatus* is 29, *Mugil cephalus* is 27, *Cynoscion regalis* is 27 and *Opsanus tau* is 11. In my investigations I find that in *Heteropneustes fossilis* it is 21, in *Clarias batrachus* it is 19, and in *Ophicephalus striatus* it is 14 (unpublished data). Gray ('54) has observed that 'Fishes with large lamellae spaced far apart often live longer out of water than those with closely packed fine lamellae. A toadfish will live for hours on the laboratory floor, a butterfish dies in a matter of minutes. Delicate closely spaced lamellae adhere together when removed from an aquatic medium and the functional surface is thus greatly reduced. It is the sluggish fishes with low metabolism that have the widely spaced lamellae'. Schottle (1931) has shown that those fishes capable of remaining out of water have gill-lamellae so arranged as not to collapse when the fish is on land. I have observed that fishes with accessory respiratory organs also have large gill-lamellae which are widely spaced. By comparing the gill-area per unit of the body weight of different fishes it becomes evident that there is a tendency of reduction of gill-area in the air-breathing fishes. The measurements of gill surface reported by Dubale (1951) did not show the same wide diversity of area found by Gray and all has a lesser area than the toad fish, which had the least surface in Gray's series. The reason being that Dubale did not take into account the gill-lamellae and only calculated on the basis of length and width of the filaments. Due to this important reason the data of Dubale is not dependable. Table III gives the comparison of the gill-area of some fishes.

TABLE III

GILL-AREA OF FISHES

No.	Species of Fish	No. of Determinations	Weight Average (Gms.)	Volume Average (c.c.)	Lamellae per mm. of filament	Gill-area (Sq. mm.) Per gram of body weight Max.	Min.	Aver.	Perc. c. of body volume Max.	Min.	Aver.
1	*Scomber Scombrus** ...	15	182	...	31	1532	802	1158	...	...	...
2	*Scomberomorus maculatus** ...	2	478	...	29	770	768	769	...	...	...
3	*Mugil caphalus** ...	9	166	...	27	1105	760	954	...	...	...
4	*Cynoscion regalis** —	6	807	...	27	593	221	373	...	...	...
5	*Opsanus tau** ...	58	233	...	11	362	94	197	...	...	...
6	*Heteropneustes fossilis* ...	11	392	36	21	538	182	359	575	190	402
7	*Clarias batrachus* ...	10	52	48	19	428	191	295	497	212	305
8	*Ophicephalus striatus*† ...	3	79	70	15	331	303	318	368	345	360

* Data from Gray (1954).

† Unpublished Data.

Table IV shows that when fishes of approximately the same volume are compared there is a definite species differences in respiratory area.

TABLE IV

RESPIRATORY AREA OF FISHES OF THE SAME VOLUME

	Species			Volume c. c.	Total gill area
1.	*Heteropneustes fossilis*	...	...	68	12945
	*Ophicephalus striatus**	...	...	70	24180
2.	*H. fossilis*	...	...	44	12910
	Clarias batrachus	...	...	44	14060
3.	*H. fossilis*	...	...	50	12454
	C. batrachus	...	...	50	13540

*Unpublished data

In the case of *Heteropneustes fossilis* it will be observed that the gill-area per gram weight of the body and per c. c. of the volume varies from 182·1 to 538·1 sq. mm. and 190·4 to 575·3 sq. mm. respectively. But as far as the total gill-area is concerned it varies from 9356 to 16680 sq. mm., not showing that marked variation, as is observed in the gill-area per unit weight and volume of the body. This points to the fact that as the fish grows in size the air-sac also develops and shares more responsibility of respiration, whereas the gill-area does not increase along with it.

It is evident that the gill-area in these two fishes with accessory respiratory organs is significantly less than those of purely water breathing fishes.

SUMMARY

1. Gill area of *Heteropneustes* and *Clarias* have been given.

2. Gill area of these two air-breathing fishes is extremely low as compared to water breathing fishes.

3. Species differences in gill-area exist whether comparision is based on unit of body weight or body volume.

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to Dr. S. M. Das, D.Sc., F.Z.S., F.Z.S.I., F.A.Z , F.N.A.Sc., Department of Zoology, Lucknow University for his constant help and guidance. I also wish to thank Principal H. L Rohtagi and Prof. K. K. Varma of D. A. V. College, Kanpur for allowing me facilities to work in the institution.

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CIRCULATION OF BLOOD IN THE RESPIRATORY REGION OF SOME FRESHWATER CATFISHES OF UTTAR PRADESH, INDIA

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INTRODUCTION

All life originated in water and adaptation to life on land is a secondary development. Although the adaptation took place in several animal phyla in extremely remote times we find even now a number of forms showing how it could come about. Such forms exist in many variations mainly in tropical freshwater fishes. In some there are special gills not collapsing in air and functional so long as they are kept moist. In others, special cavities, coated with respiratory capillaries are kept filled with air. Some have developed accessory respiratory organs to increase the efficiency or to supplement the action of the gills. Many of these adaptations permit air-breathing, during deficiency of oxygen dissolved in water, allowing some obviously aquatic teleosts to become temporary land-dwellers. Aerial respiration provides an example of a fundamental change in the functioning of one of the main systems of the body with the restultant modifications of the correlated structures. The part of the circulatory system, which is intimately connected with the respiratory organs shows, therefore, marked modifications along with the elaboration of the respiratory mechanism.

The anatomy and histology of the accessory respiratory organs in freshwater fishes have been worked out in some detail by many in India as well as abroad. But to my knowledge little or no attention has deen paid by early or recent workers in the resultant modifications of the circulatory structures correlated with the varied adaptations of the respiratory mechanism in freshwater fishes with aerial respiration, except, Hyrtl (1853) and Burne (1896) on the aortic arch system of *Saccobranchus* (*Heteropneustes*) *fossilis*, Lele (1932) on the circulation of blood in the air-chamber of *Ophicephalus punctatus*, Wu and Wei Chang ('46) on the arterial system of gills and supra-branchial cavities of *Ophicephalus argus*, Das & Saxena ('54) on new observa-

tions in the circulatory system of *Ophicephalus striatus*, Saxena ('54) on new observations on the afferent branchial system of *Heteropneustes fossilis*, Das & Saxena ('56) on the circulation of blood in the respiratory region of *Labeo rohita* and *Ophicephalus striatus* and Saxena ('56 a, b, c & d) on the afferent and efferent arteries of *Mastacembelus armatus*, *Rita rita* and *Anabas testudineus*.

I have selected *Rita rita* Hamilton, *Clarias batrachus* L. and *Heteropneustes fossilis* Bloch, all the three belonging to the order Ostariophysi and sub-order Siluroidea, the later two with accessory respiratory organs in the form of arborescent organs and air-sacs respectively and the former without any accessory respiratory organ but is known to survive out of water for some period. To my knowledge the present contribution shows for the first time in detail how the circulatory system in the respiratory region has become modified and adapted to subserve aerial respiration in these fishes.

MATERIAL AND METHODS

The fishes were procured in fresh condition from the fish markets of Kanpur and live specimen were also obtained from fishermen. The afferent arteries were injected through the ventral aorta by gum arabic carmine and gelatine carmine mass and was fixed in alcohol for a week and then dissected. Starch carmine mass was found unsatisfactory in these fishes. The injection was given while the heart was still beating to ensure proper circulation of the injection mass into the finest vessels. The efferent and venous systems were not injected, as the fish after being narcotized or rapidly killed and placed in 70 percent alcohol or 10 percent formaiin glycerine mixture showed the finest vessels on dissection after a week distinctly, due to coagulation of blood in them. All the dissections were done with the help of stereoscopic binocular microscope to expose in detail the finer blood vessels. The blood vessels were traced into and across the respiratory surfaces and accurate line drawings made from the dissections.

AFFERENT BRANCHIAL SYSTEM

Rita rita—The bulbus (conus) arteriosus gives rise to the ventral aorta (Fig. 1), which after passing through the pericardium anteriorly, runs forward along the under surface of the floor of the pharynx in the mid-ventral line. It extends from the ventral end of the third branchial arch up to the ventral end of the first branchial arch where it terminates by dividing into the first pair of afferent branchial arteries. The ventral aorta immediately after piercing the pericardium gives off a single branch which is posteriorly directed. This branch after running for a very short distance divides into two, the left and right branches. Each of these branches divide again into two, the third and fourth afferent branchial arteries. Along its course, in level with the ventral end of the second branchial arch, the ventral aorta gives rise to the second pair of afferent branchial arteries parallel with the first and the third.

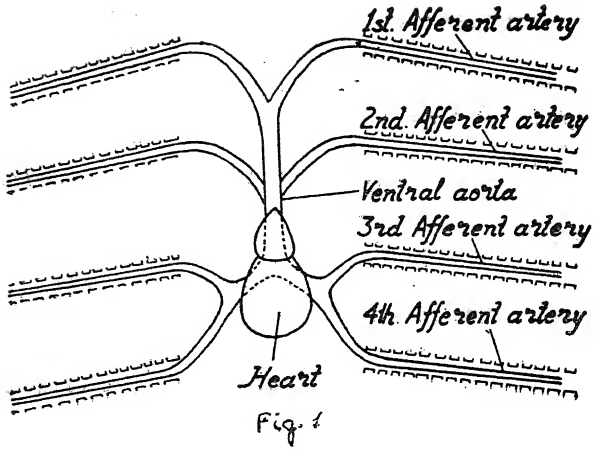


Fig. 1

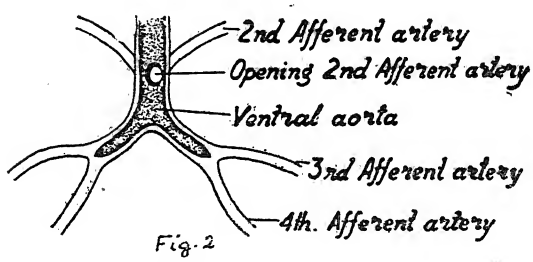


Fig. 2

Fig. 1. Afferent branchial system of *Rita rita*.

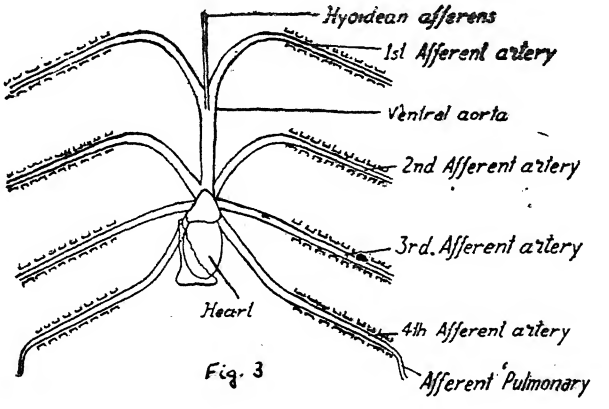
Fig. 2. Ventral aorta cut open to expose the openings of the second, third and fourth afferent arteries in *Rita rita*.

The first pair of afferent arteries originates by the bifurcation of the ventral aorta, while the second pair of afferent arteries originates from a single aperture (Fig. 2) in the roof of the ventral aorta. The third and fourth afferent arteries of each side arise from a common root. The two common roots of the third and fourth afferent arteries arise from a single root opening by an aperture in the dorsal wall of the ventral aorta. Thus four afferent arteries, the third and fourth pairs, originate from a single aperture in the ventral aorta. The ratio between the distances of origin of the first and second pairs of afferent arteries from the bulbus is always 3:1, and the common origin of the third and fourth pair is immediately after the bulbus.

All these afferent arteries run for a distance along the ventral surface of the floor of the pharynx before traversing their corresponding branchial arches, where they run along the grooved outer surfaces and lie externally to the efferent branchial arteries. During its course along the branchial arch, each afferent artery gives out a series of paired afferent lamellar arteries corresponding to the number of gill-lamellae present. Each afferent lamellar artery communicates with the efferent lamellar artery through cross-vessels as well as capillaries.

Heteropneustes fossilis:—The bulbus (conus) arteriosus is narrowed and continued anteriorly as the ventral aorta (Fig. 3). After piercing the pericardium anteriorly,

it runs forward along the under surface of the floor of the pharynx in the mid-ventral line. The ventral aorta extends from the ventral end of the third branchial arch up to the ventral end of the first branchial arch where it terminates by dividing into the first pair of afferent branchial arteries. Before the ventral aorta divides it gives out a single median artery, the hyoidean afferens, which runs forward for a short distance and supplies the hyoidean arch. The ventral aorta, immediately after piercing the pericardium gives off two branches, one directed forward and the other backward. The forwardly directed branch divides into two, immediately after it is given out, to form the right and left second afferent branchial arteries. The second branch which is backwardly directed also divides into two, the right and left, each one of which in turn divides again into two, forming the third and the fourth affernnt branchial arteries of its side.



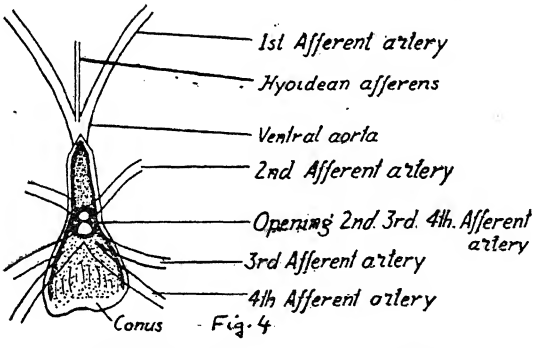


Fig. 3. Afferent branchial system of *Heteropneustes fossilis.*

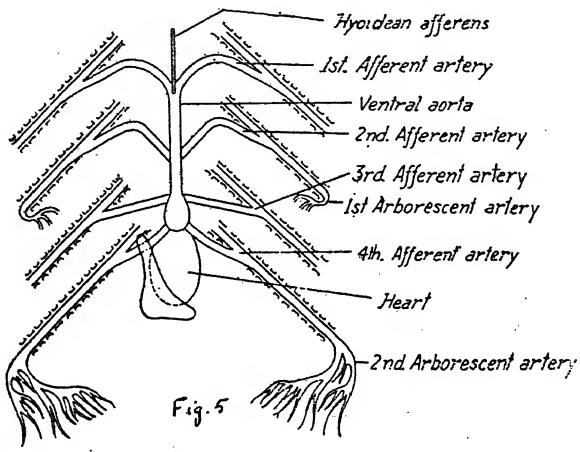
Fig. 4. Ventral aorta cut open to expose the openings of the second, third and fourth afferent arteries in *H. fossilis.*

The first pair of afferent arteries are formed by the division of the ventral aorta anteriorly. The second, third and the fourth pairs of afferent arteries (Fig. 4) all originate from a common opening in the roof of the ventral aorta. The third and fourth afferent arteries of each side arise from a common root. The two common roots of the third and fourth afferent arteries arise from a single common root. The common root of the second pair of afferent arteries and the single common root of

the third and fourth pairs of afferent arteries originate from a single aperture in the dorsal wall of the ventral aorta. Thus, the six afferent arteries, the right and left second, third and fourth afferent arteries, all originate from the ventral aorta from the single opening situated on the dorsal wall.

All these afferent arteries run for a distance along the ventral surface of the floor of the pharynx before traversing their corresponding branchial arch. Each one of these afferent arteries after entering its corresponding branchial arch, runs along the grooved outer surface and lies externally to the efferent branchial artery. During its course along the branchial arch, each afferent artery gives out a series of paired afferent lamellar arteries corresponding to the number of gill-lamellae present. Each afferent lamellar artery communicates with the efferent lamellar artery through cross-vessels and capillaries.

Clarias batrachus:—The bulbus (conus) arteriosus narrows and continues as the ventral aorta (Fig. 5). After piercing the pericardium anteriorly, the ventral aorta runs forward along the under surface of the floor of the pharynx in the mid-ventral line. The ventral aorta extends from the ventral end of the of the third branchial arch up to the ventral end of the first branchial arch, where it terminates by dividing into the first pair of afferent branchial arteries. Before the ventral aorta



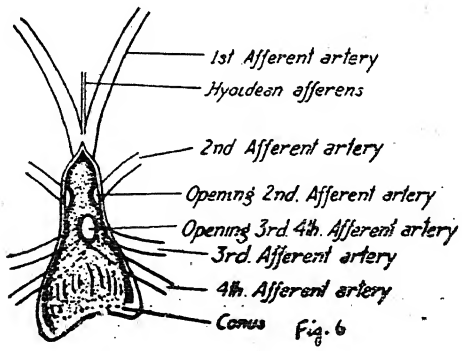


Fig. 5. Afferent branchial system of *Clarias batrachus*.

Fig. 6. Ventral aorta cut open to expose the openings of the second, third and fourth afferent arteries in *C. batrachus*.

bifurcates to form the first pair of afferent arteries, it gives out a single median artery, the hyoidean afferens, which runs forward for a short distance and supplies the hyoid arch. Immediately after piercing the pericardium the ventral aorta gives off three pairs of afferent arteries. The third and the fourth pairs of afferent arteries are given off in level with the ventral end of the third branchial arch. The third pair of afferent arteries runs out almost horizontally, while the fourth pair of the afferent arteries curves backward and runs posteriorly for a short distance before traversing the fourth gill-arch. The second pair of afferent branchial arteries, arising separately, extends forward for a distance and then curves backward in level with the ventral end of the second branchial arch which it traverses.

The first pair of afferent arteries originates by the division of the ventral aorta anteriorly, while the second pair of afferent arteries originate dorso-laterally from separate openings in the ventral aorta (Fig. 6). The third and fourth afferent arteries of each side arise from a common root; and the two common roots, the right and left, arise from a single aperture in the dorsal wall of the ventral aorta. Thus, the four arteries, the right and left third and fourth afferent arteries have a common origin from the ventral aorta. The ratio between the distances of origin of the first and second pairs of afferent arteries from the bulbus is always 5:1 and the common origin of the third and fourth pairs of afferent arteries is immediately after the bulbus.

All the four pairs of afferent arteries run for a distance along the ventral surface of the floor of the pharynx before traversing their corresponding branchial arches from the meso-anterior side, where they run postero-laterally along their grooved ventral surfaces and lie externally to the efferent branchial arteries. During its course along the branchial arch, each branchial artery does not give out branches to the filaments of the mesial half, but a series of paired afferent lamellar arteries corresponding to the number of the gill-lamellae present are given out to the mesial half by a recurrent artery which branches mid-way and runs antero-mesially, and the remaining half by the main afferent artery. Each afferent lamellar artery communicates with the efferent lamellar artery through the cross-vessels and capillaries.

EFFERENT BRANCHIAL SYSTEM

Rita rita :—The efferent lamaller arteries collect blood from the lamella and its secondary folds and then open proximally into the efferent branchial artery. Each efferent artery arises at the antero-ventral end of a gill-bearing arch and runs along the grooved outer surfaces of the ceratobranchial, lying internally to the afferent artery. It leaves the arch at the postero-dorsal end. The first efferent

artery on leaving the first branchial arch curves round the second internal branchial cleft and runs posteriorly to meet the second efferent branchial artery (Fig 7), the

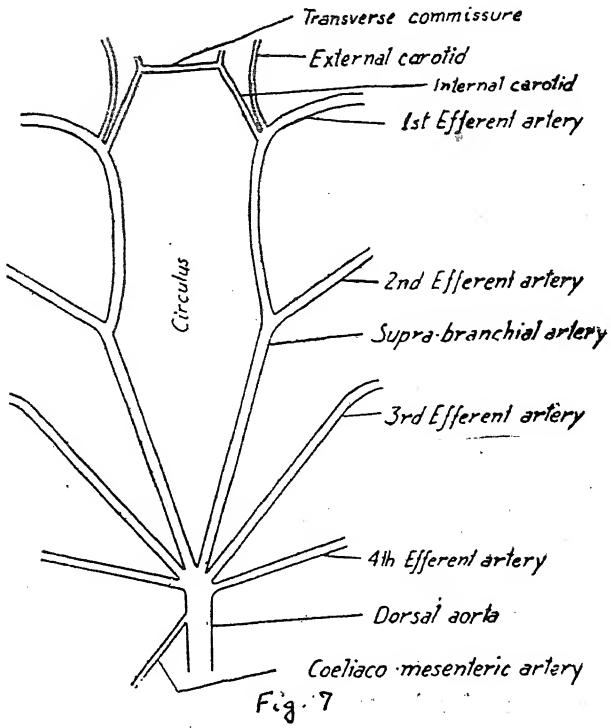


Fig. 7. Efferent branchial arteries of *Rita rita*.

two together forming the first and only supra-branchial artery. The supra-branchial artery of each side runs posteriorly for a distance and unites in the region of the anterior part of the basi-occipital bone, where the third and fourth pairs of efferent arteries also join independently to form the dorsal aorta. The third efferent artery after emerging from the third branchial arch curves round the fourth internal branchial cleft, and posteriorly towards the middle of the basi-occipital bone, to open into the anterior end of the dorsal aorta. This head of the aorta is thus formed by six vessels, three on each side *viz.* the supra-branchial, the third and the fourth efferent arteries.

The first efferent artery gives out two arteries anteriorly, the external and internal carotids. The external carotid arises immediately after the first efferent artery emerges out of the gill-arch and runs towards the region of the snout. The internal carotid arises adjacent to the external carotid and runs meso-anteriorly and communicates with the fellow of the opposite side through the transverse commissure (anterior commissure).

Only the first and second efferent arteries open into the *circulus cephalicus*, while the third and fourth efferent arteries open separately into the dorsal aorta immediately after it. The circulus is thus formed by the anterior commissure from the internal carotid, the posterior part of the first pair of efferent arteries, and the pair of supra-branchial arteries.

Heteropneustes fossilis :—The blood is collected by the efferent lamellar arteries from the lamella and its secondary folds. The efferent lamellar artery then opens proximally into the efferent branchial artery. Each efferent artery arising at the antero-ventral end of the gill-bearing arch emerges out at its postero-dorsal end. The first efferent branchial artery on leaving its branchial arch, curves round the second internal branchial cleft and runs posteriorly to meet the second efferent branchial artery (Fig. 8), the two together forming the first supra branchial artery. The third efferent branchial artery on leaving the third branchial arch, curves round the fourth internal branchial cleft, and runs posteriorly to meet the fourth efferent branchial artery of its own side, the two together forming the second supra-branchial artery. The first supra-branchial arteries of the two sides run posteriorly and the second supra-branchial runs inwards, till they reach the level of the anterior part of the basi-occipital bone, where they join to form the dorsal aorta, the coeliaco-mesenteric arising from the junction of the two pairs of the supra-branchials. The head of the dorsal aorta is thus formed by the first and second pairs of the supra-branchial arteries.

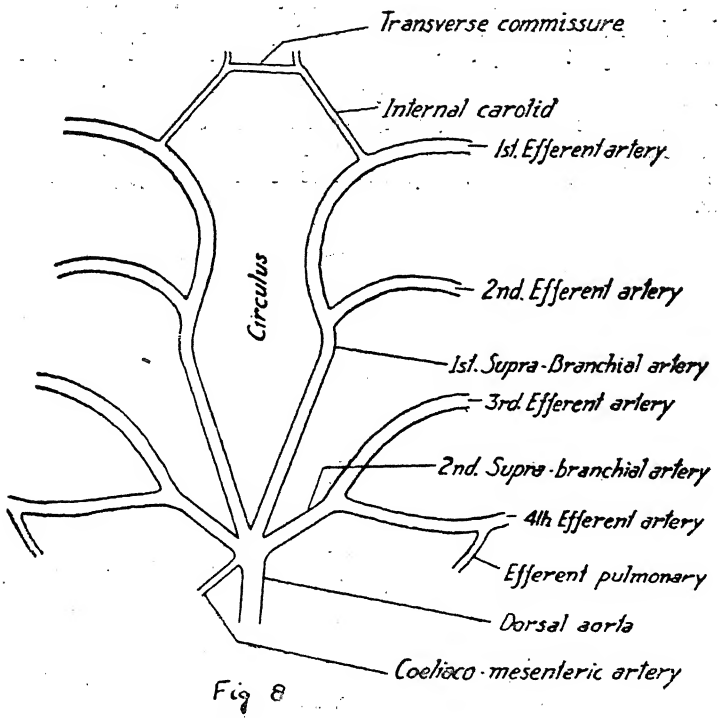


Fig. 8. Efferent branchial arteries of *Heteropneustes fossilis*.

The first efferent artery gives out anteriorly the internal carotid which runs meso-anteriorly and communicates through a branch, the anterior commissure, with the fellow of the opposite side.

Only the first and second efferent arteries open into the *circulus cephalicus*, and the third and fourth efferent arteries join to form the second supra-branchial arteries, which open into the dorsal aorta at the junction of the first pair of supra-branchial arteries in the region of the basi-occipital bone. The circulus is thus formed by the

anterior commissure from the internal carotid, the posterior part of the first pair of efferent arteries, and the first pair of supra-branchial arteries.

Clarias batrachus:—The blood, after passing through each lamella and its secondary folds, is collected by the efferent lamellar arteries, which open proximally into the efferent branchial artery. In each gill-arch there is a pair of efferent branchial arteries—the pretrematic and post-trematic, situated on either side of the afferent arteries on the ventral side of the ceratobranchial. Pretrematic artery receives the efferent lamellar arteries from the anterior row of gill-filaments and the post-trematic from the posterior row of gill-filaments of the same gill-arch. The pre-and post-tramatic arteries of each gill-arch unite at the lateral tip of the ceratobranchial into a single efferent artery. The first efferent artery on leaving the first branchial-arch, curves round the second internal branchial cleft and runs posteriorly to meet the second efferent artery (Fig. 9), the two together forming the first and only supra-branchial artery. The supra-branchial of the two sides run posteriorly for a distance and then unite together; the region of union receiving the third and fourth efferent arteries of the right and left sides to form the dorsal aorta in the region of the anterior part of the basi-occipital bone. The third efferent artery after emerging from the third branchial arch curves round the fourth internal branchial cleft, and runs posteriorly towards the middle of the basi-occipital bone.

The first efferent artery gives out anteriorly three arteries immediately after emerging from the first branchial arch, the internal carotid, epihyoidean and the hyoidean. The interal carotid runs meso-anteriorly and communicates through a branch, the anterior commissure (transverse commissure), with the fellow of the opposite side.

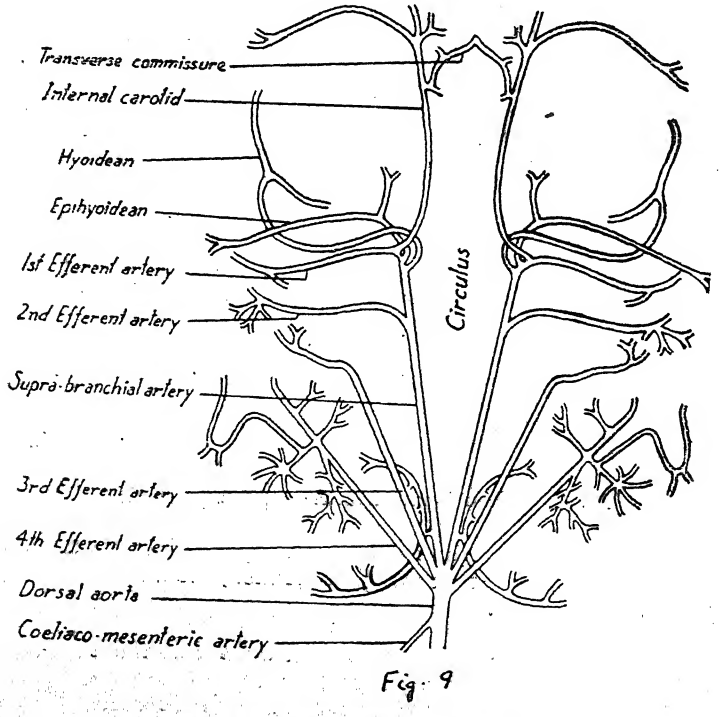


Fig. 9. Efferent branchial arteries of *Clarias batrachus*.

Only the first and second efferent arteries open into the *circulus cephalicus*, while the third and fourth efferent arteries open separately at the junction of the pair of supra-branchial arteries. The circulus is formed by the anterior commissure from the internal carotid, the posterior part of the first pair of efferent arteries, and the pair of supra-branchial arteries.

The head of the dorsal aorta is formed by the first pair of supra-branchial arteries, where it also receives the third and fourth pairs of efferent arteries opening independently.

Some capillaries from the arborescent organ borne on the fourth gill-arch join to form a single coronary artery (Fig. 12) which is found on one side only. The coronary artery may be present on the left or the right side and both the conditions occur in equal ratio in the specimens dissected by me. The coronary artery runs anteriorly, lying dorsally to the sinus venosus and the inferior jugular vein and on reaching the mid-distance between the ventral ends of the third and fourth branchial arches it divides into five main branches, three of which run anteriorly and two are directed posteriorly. The anterior median branch on reaching the conus divides and sub-divides on the wall of conus and also extends to the muscles of the wall of ventricle. The two anterior lateral branches run on the sides of the ventral aorta, where as the two posterior branches (the pharyngeal branches of the coronary artery) supply the muscle groups situated on the floor of the pharynx.

VENOUS SYSTEM IN THE BRANCHIAL REGION

Rita rita :—The venous blood from the respiratory region is collected by the paired anterior cardinal veins and a single inferior jugular vein (Fig. 10). Each anterior cardinal vein begins by collecting blood from the anterior part of the head and after traversing the orbit comes to lie on the ventral surface of the cranium above the dorsal extremities of the branchial arches. During its course it receives vessels brining blood from the brain and other parts of the head. On leaving the head each anterior cardinal curves downward to run along the outer surface of the posterior part of the cleithrum, where it bends at right angles and runs mesially. Each finally pierces and enters the antero-ventral part of the pericardial cavity to open into the sinus venosus at its antero-lateral extremity. Before opening into the sinus venosus the right anterior cardinal receives the single inferior jugular vein present only on this side.

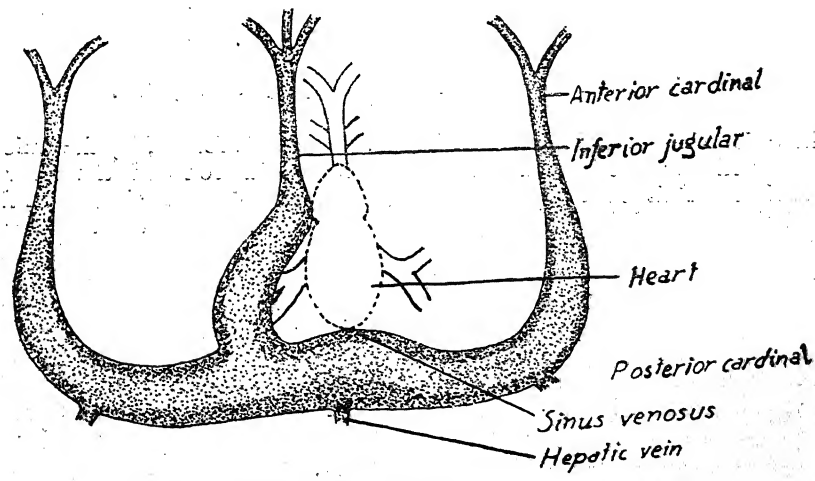


Fig. 10. Venous system in the respiratory region of *Rita rita*.

The right inferior jugular vein is formed at the anterior end of the floor of the buccal cavity by the union of the branches from both sides of the hyoid arch. It runs posteriorly in the mid-ventral line till it reaches the conus, where it curves towards the right and runs alongside of the heart and finally opens into the right anterior cardinal vien.

Heteropneustes fossilis :—The venous blood from the respiratory region is collected by the paired anterior cardinal veins and a single inferior jugular vein (Fig. 11) Each anterior cardinal vein begins by collecting blood from the anterior part of the head and after traversing the orbit comes to lie on the ventral surface of the cranium above the dorsal exremeties of the branchial arches. During its course it receives vessels bringing blood from the brain and other parts of the head. On leaving the head it curves downward to run along the outer surface of the posterior part of the cleithrum, where it bends at right angles and runs mesially. It finally perces and enters the antero-ventral part of the pericardial cavity to open into the sinus venosus at its antero-lateral extremity. Before opening into the sinus venosus the left anterior cardinal receives the single inferior jugular vein.

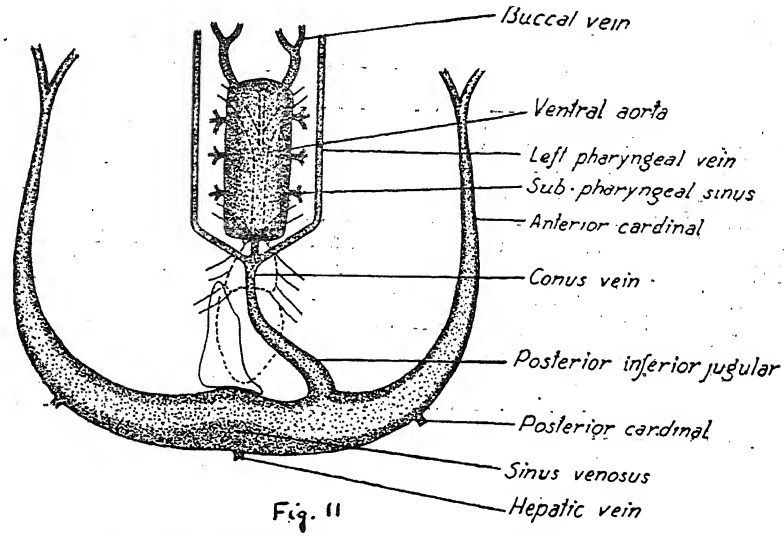


Fig. 11. Venous system in the respiratory region of *H. fossilis*.

There is a large sub-pharyngeal sinus, which is formed by the union of the two bucco-hyoidean veins bringing blood from the hyoid arch and the floor of the buccal cavity. This thin walled sinus containing blood lies between the inner margins of the branchial arches extending from two millimeter anterior to the ventral end of the first branchial arch upto the ventral end of the third branchial arch. The sub-pharyngeal sinus receives small vessels bringing blood from muscle groups situated in the pharyngeal region. It communicates with the left anterior cardinal by a single inferior jugular vein, which receives two large lateral pharyngeal veins bringing blood from the lateral sides of the floor of the pharynx. There is a single median stout short vein, the sub-pharyngeal vein connecting the sub pharyngeal sinus with the inferior jugular vein. Thus the two lateral pharyngeal veins and the sub-pharyngeal vein open together into the single inferior jugular vein on the left side. There is a small (conus) vein which drains blood from the wall of the conus into the inferior jugular vein.

Clarias batrachus:—The venous blood from the respiratory region is collected by the paired anterior cardinal veins and a single inferior jugular vein (Fig. 12). Each anterior cardinal vein begins by collecting blood from the eye of its own side and the adjacent parts, and after traversing the orbit comes to lie on the ventral surface of the cranium above the dorsal extremities of the branchial arches. During its course it receives vessels bringing blood from the brain and other parts of the head. On leaving the head it curves downward to run along the outer surface of the posterior part of the cleithrum where it bends at right angles and runs mesially. Finally it pierces and enters the antero-ventral part of the pericardial cavity to open into the sinus venosus at its antero-lateral extremity. Before opening into the sinus venosus the left anterior cardinal vein receives the inferior jugular vein.

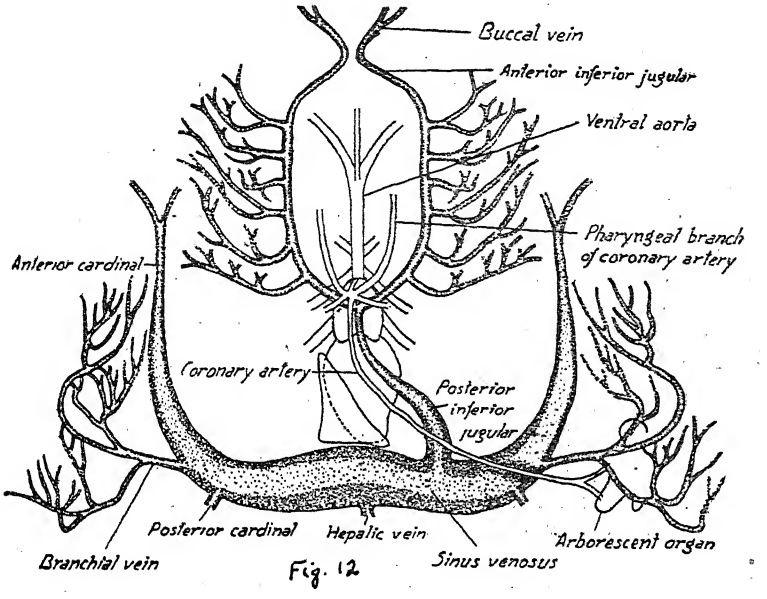


Fig. 12. Venous system in the respiratory region of *C. batrachus*.

The lateral pharyngeal veins are formed at the anterior end of the floor of the buccal cavity on each side by the union of branches from the hyoid arch. The lateral pharyngeal veins run posteriorly and curve inwardly towards the mid-ventral line of the floor of the pharynx, and then diverge before uniting to run backward parallel to each other on either side of the ventral aorta. The lateral pharyngeal vein of each side during its course receives a number of branches from the muscle groups situated on the floor of the pharynx. In level with the ventral end of the third branchial arch the lateral pharyngeal veins of both the sides join to form a single vein, the inferior jugular, which runs posteriorly for a distance in the mid-ventral line and then curves to the left to join the left anterior cardinal.

Although it is the left inferior jugular vein which is generally found in the adult, in a few it is the right one which is present, the left being completely absent. This variation has been found in about twenty five percent of the specimens dissected.

Heteropneustes fossilis :—The fourth afferent artery of each side is considerably larger than others, and after giving branches to the gill-filaments it emerges out of the gill-arch to continue along the ventral wall of the air-sac right upto its posterior extremity as the afferent 'Pulmonary' artery. During its course on the ventral wall of the air-sac it gives out lateral branches to supply blood to the wall of the enormously elongated air-sac.

The capillaries in the wall of the air-sac join to form a single artery, the efferent 'Pulmonary' artery, which joins the fourth efferent artery immediately after it emerges from the gill-arch.

Clarias batrachus :—The second and fourth pairs of afferent arteries are larger than the first and the third pairs of afferent arteries, as they supply, in addition to the double row of gill-filaments, the first and second arborescent organs which are connected to latero-dorsal part of the epibranchial, and the membrane lining the branchial chamber.

The first afferent artery continues after supplying the double row of gill-filaments to supply the lining of the dorsal wall of the branchial chamber where it finally ramifies. The third afferent artery also continues to supply the lining of the lateral and posterior wall of the branchial chamber.

The second pair of afferent arteries after emerging from the second gill-arch turns dorso-mesially and gives off five arteries, four to the corresponding four branches of the first arborescent organ and the fifth to the lining of the anterior and mesial wall of the branchial chamber. These divide and subdivide to numerous small branches and supply the lobes of the first arborescent organ and the anterior and lateral internal lining membrane of the branchial chamber.

The fourth pair of afferent arteries after emerging from the fourth gill-arch turns dorsally and gives off three main branches, two to the second arborescent organ and one to the lining of the lateral and ventral wall of the branchial chamber. These divide and subdivide into numerous small branches and supply the lobes of the arborescent organ and the mesial and ventral lining of the branchial chamber.

The first efferent artery receives a branch from the lining membrane of the anterior side of the branchial chamber. The third efferent artery receives two small branches from the lining membrane of the posterior wall of the branchial chamber. The supra-branchial artery near its base, receives a large branch formed by the union of two branches, which collect blood from the lining membrane of the mesial and posterior wall of the branchial chamber.

The second efferent artery receives in addition to the branch from the lining membrane of the anterior and dorsal wall of the branchial chamber, three small branches and one large branch from the arborescent organ borne on the second gill-arch. The fourth efferent artery receives in addition to the branch from the lining membrane of the lateral and ventral wall of the branchial chamber, two large branches from the arborescent organ borne on the fourth gill-arch.

The blood supply of the aborescent organ and branchial chamber which is so important to the fish that by this means it is enabled to perform aerial respiration, is given in the Table I.

TABLE I

Circulation of Blood in the Arborescent Organ and the Branchial Chamber of *Clarias batrachus*

Region	Blood supplied by	Blood collected by
Dorsal wall ...	Branch of 1st afferent artery	2nd efferent artery.
Anterior wall ...	,, ,, 2nd ,, ,,	1st & 2nd efferent arteries
Mesial wall ...	,, ,, ,, ,, ,,	Supra-branchial artery.
Posterior wall ...	,, ,, 3rd ,, ,,	3rd efferent & supra-branchial arteries.
Lateral wall ...	,, ,, 3rd & 4th ,, ,,	4th efferent artery.
Ventral wall ...	,, ,, 4th ,, ,,	4th ,, ,,
1st arborescent organ ...	2nd afferent artery	2nd ,, ,,
2nd ,, ,, ...	4th afferent artery	4th ,, ,,

COURSE OF CIRCULATION ON BLOOD

Rita rita :—The blood collected in the sinus venosus through the anterior and posterior cardinals and the hepatic veins is passed to the ventral aorta through the ventricle. From the ventral aorta this deoxygenated blood is sent for oxygenation to the gills through the four pairs of afferent arteries. The oxygenated blood from the gills is collected by the efferent arteries (Fig. 13) and sent for circulation to the

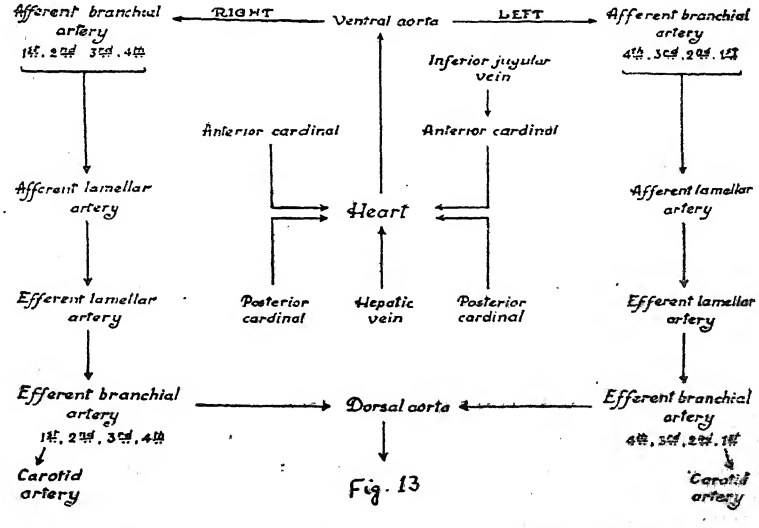


Fig. 13

Fig. 13. Course of circulation in the respiratory region of *R. rita*.

various parts of the head through the external and internal carotids from the first efferent arteries and the blood from the second, third and fourth efferent arteries is passed to the dorsal aorta from where it is sent to the various parts of the body.

Heteropneustes fossilis :—The blood collected by the anterior and posterior cardinals and the hepatic vein in the sinus venosus is passed to the ventral aorta through the ventricle. From the ventral aorta this deoxygenated blood is sent for oxygenation to the gills through the four pairs of afferent arteries. The fourth pair of afferent arteries also carry blood, after supplying the fourth gill-arch, to the air-sac for further oxygenation, and the blood from the walls of the air-sac is collected by the fourth pair of efferent arteries. The oxygenated blood from the gills is collected by the efferent arteries (Fig. 14) and is sent for circulation to the various parts of the head through the external and internal carotids from the first efferent arteries and the blood from the second, third and fourth efferent arteries is passed to the dorsal aorta from where it is sent to the various parts of the body.

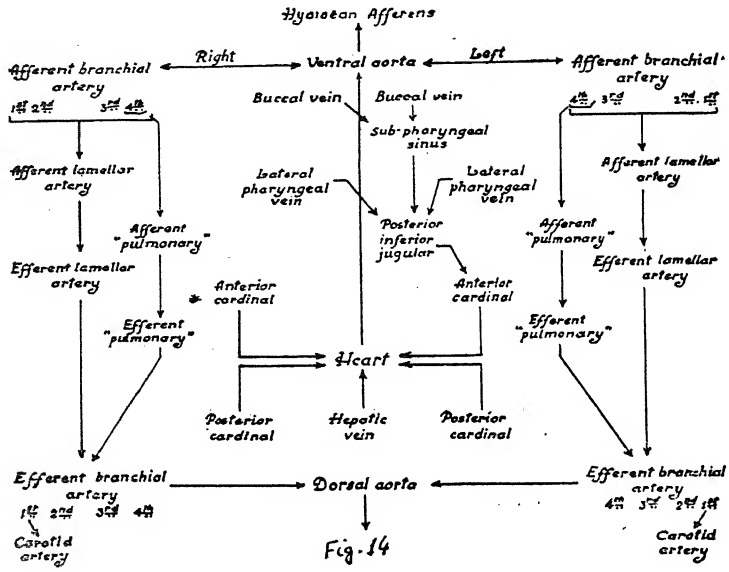


Fig. 14. Course of circulation in the respiratory region of *H. fossilis*.

Clarias batrachus:—The blood collected through the anterior and posterior cardinals and the hepatic vein in the sinus venosus in passed to the ventral aorta through the ventricle. This deoxygenated blood is sent for oxygenation to the gills through the four pairs of afferent arteries arising from the ventral aorta. The second and fourth pairs of afferent arteries, after supplying the blood to the gill-filaments of these arches, also supply blood to the arborescent organs borne on them for further oxygenation. The oxygenated blood from the gills is collected by the efferent arteries (Fig. 15), the second and fourth efferent arteries receive the blood from the arborescent organ and the lining membrane of the branchial chamber. The blood is sent for circulation to the various parts of the head through the external carotid, epihyoidean and hyoidean arteries from the first efferent artery and the blood from the second, third and fourth efferent arteries is passed to the dorsal aorta from where it is sent to the various parts of the body.

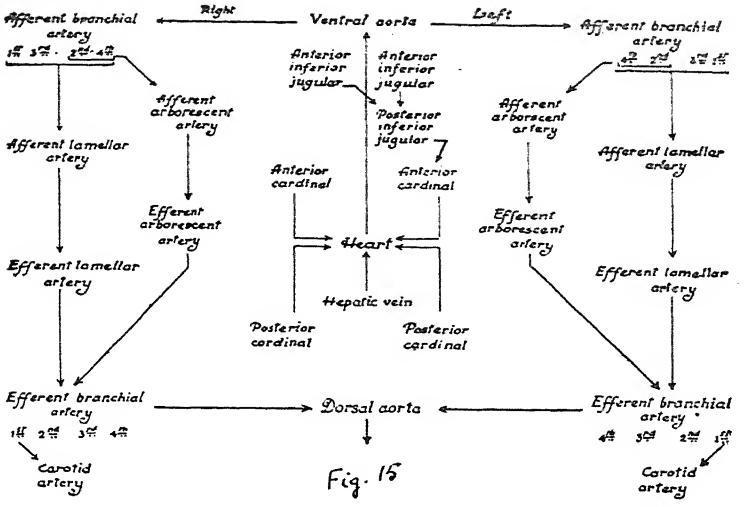


Fig. 15

Fig, 15. Course of circulation in the respiratory region of *C. batrachus.*

DISCUSSION

The modifications in the chief blood vessels of the respiratory region have, however, not been satisfactorily worked out in freshwater fishes of India, with a view to compare aquatic and aquatic-aerial species. Carter and Beadle (1931) while discussing the blood supply of the respiratory organs in fishes, went to the extent of saying 'that the arterial supply of the respiratory organs as a rule, is not of great interest.' More over they maintained 'if the accessory organ is on the direct course of branchial circulation (as in *Hypopomus, Clarias* and *Saccobranchus* etc.) it is to be expected that no modification of either the main venous or arterial circulation would occur.' Das (1940) said that the arterial supply of blood in air-breathing fishes is not of any special interest. In reviewing the data compiled by Carter and Beadle (1931) it is at once obvious that the accessory respiratory organs of the air-breathing fishes are supplied by blood of multifarious origin. It would seem that there are two possible factors governing the resultant blood supply, namely, the initial organ from which the accessory organ is derived, and the morphological situation of the accessory organ. It matters little what kind of blood the vessels may contain.

No published work is available on the circulatory system of *Rita rita.* In *Rita* the second pair of afferent arteries originates from one common aperture; so also the third and fourth afferent arteries of both sides originate from another common aperture. In *Heteropneustes* Burne (1896) did not go into details of circulation of

blood in the respiratory region, but only traced the fourth afferent arteries to the air sac, to check up the work of Hyrtl (1853). According to Hyrte the fourth afferent artery of the left and the first afferent artery on the right surpasses all the other afferent arteries in length to supply the air-sacs. Burne's observations do not answer to this description, for he states that the afferent arteries are symmetrical. I have observed that only the two fourth afferent arteries are longer than the others and supply the air-sacs.

In *Clarias lazera* Nawar (1955) has not observed the hyoidean afferens and while describing the origin of the afferent arteries he mentions, 'the second pair of afferent arteries takes its origin directly from the antero-dorsal wall of the bulbus, while the third and fourth pairs branch from the common short trunk which originates from the mid-dorsal surface of the bulbus; internally its origin is marked by a wide oval opening'. As observed by me in *C. batrachus,* the opening for the common origin of the third and fourth pairs of afferent arteries is situated in the dorsal wall of the ventral aorta near its origin from the bulbus, while the second pair of afferent arteries originates a little anterior to the common aperture of the third and fourth afferent arteries by two independent lateral openings. These openings are so closely situated to the anterior end of the bulbus that they appear to originate from the bulbus itself.

The elaboration of the efferent branchial arteries specially those vessels arising from the circulus cephalicus, have not been traced in the past in any detail, except by Ridewood in 1899. In *Rita rita* and *Clarias batrachus* I observed that the first and the second pairs of efferent arteries open into the circulus and the third and fourth pairs of efferent arteries open into the aorta independently, immediately behind the circulus. In *Heteropneustes fossilis* the first and second pairs of efferent arteries open into the circulus and the third and fourth efferent arteries of each side join together before opening into the aorta immediatly after the circulus. The coronary artery in the *Clarias,* bringing blood from the accessary respiratory (arborescent) organ to the heart muscles has also not been described, to my knowledge in any other Indian fresh-water fish.

No satisfactory account of the venous circulation in the respiratory region is obtainable from published litrature on the subject. The formation of large sub-pharyngeal sinus collecting blood from the floor of the pharynx and the buccal cavity in *Heteropneustes* is similar to the condition already reported in *Ophicephalus striatus* (Das & Saxena '54). The present paper gives, to my knowledge, the first report of the sub-pharyngeal sinus in *Heteropneustes*.

The circulatory system in the respiratory region of *Rita* (without any accessory respiratory organ but able to survive out of water), *Clarias* (with arborescent organs) and *Heteropneustes* (with air-sacs) show marked differences when compared (Table II).

TABLE II

Table of contrasts of the Circulatory system in the Respiratory Region of the fishes *Clarias batrachus Heteropneustes fossilis* and *Rita rita*

Systems		*Clarias batrachus*	*Heteropneustes fossilis*	*Rita rita*
Afferent system...	1.	The ventral aorta gives off two pairs of afferent arteries in level with the ventral end of the third branchial arch, one pair a little anterior to it, and one pair in level with the ventral end of the first branchial arch.	The ventral aorta gives off three pairs of afferent arteries in level with the ventral end of the third branchial arch and one pair in level with the ventral end of the first branchial arch.	The ventral aorta gives off two pairs of afferent arteries in level with the ventral end of the third branchial arch, one pair a little anterior to it and one pair in level with the ventral end of the first branchial arch.
	2.	The four afferent arteries supply the corresponding gill arches.	The four afferent arteries supply the corresponding gill-arches.	The four afferent arteries supply the corresponding gill-arches.
	3.	The second pair of afferent arteries originate from separate openings in the ventral aorta; while the third and fourth afferent arteries arise from a common aperture in the roof of the ventral aorta.	The second, third and fourth pairs of afferent arteries all originate from a common aperture in the roof of ventral aorta.	The second pair of afferents arteries originates from a single aperture and the third and fourth pairs of afferent arteries from a second opening.
	4.	The hyoidean afferens is present and supplies the hyoidean arch.	The hyoidean afferens is present in this fish also and supplies the hyoidean arch.	The hyoidean afferens is absent.
Efferent system...	5.	The first and second efferent arteries join to form the supra-branchial which meets its fellow of the opposite side at the junction of the third and fourth efferent arteries from both sides and then form the dorsal aorta.	The first and second efferents join to form the first supra-branchial and the third and fourth form the second supra-branchial; and both these supra-branchials of each side meet to form the dorsal aorta.	The first and the second efferent arteries join to form the supra-branchial which meets its fellow of the opposite side at the junction of the third and fourth efferent arteries from both sides and then from the dorsal aorta.
	6.	Coronary artery present.	It is absent.	Coronary artery absent.
Venous system...	7.	The anterior cardinal of the left side generally receives a single inferior jugular vein. Sometimes the right anterior cardinal receives the single inferior jugular vein.	It is always the left anterior cardinal which receives the inferior jugular vein	It is always the left anterior cardinal which receives the inferior jugular vein.
	8.	No venous sinus is present.	A large venous sinus, the sub-pharyngeal sinus is formed.	No venous sinus present.

In *Heteropneustes* the air-sacs are supplied by the fourth afferent artery and the blood is collected by the corresponding efferent arteries. In *Clarias* the arborescent organs are supplied by the second and fourth efferent arteries and the aerated blood is collected by the corresponding efferent arteries.

SUMMARY

The third and fourth pairs of afferent arteries originate from a common aperture in *Rita* and *Clarias*. The second pair in *Rita* originates from a common aperture in the ventral aorta and in *Clarias* from independent apertures. In *Heteropneustes* the second, third and fourth pairs of afferent arteries originate from a single aperture. In *Rita* and *Clarias* the first and second efferent arteries of both the sides join to form the first supra-branchial artery of either side, and the two supra-branchial arteries join to form the dorsal aorta, at this junction the third and fourth efferent arteries also join independently. In *Heteropneustes* the the first and second efferents form first supra-branchial and the other two efferents form the second supa-branchial and the two supra-branchials join to form the dorsal aorta. In all the three fishes the first and second efferents only communicate directly with the circulus. In *Heteropneustes* a sub-pharyngeal sinus is present. The coronary artery is present in *Clarias* only. In *Heteropneustes* the blood is supplied to the air-sac by the fourth afferents and collected by the corresponding efferents. In *Clarias* the second and fourth afferents supply the arborescent organs and the blood from these organs is collected by the corresponding efferents.

ACKNOWLEDGEMENTS

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CIRCULATION OF BLOOD IN THE RESPIRATORY REGION OF *ANABAS TESTUDINEUS*, (BLOCH)

By

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I. INTRODUCTION

Gills have their greatest development among the teleosts and considering the respiratory area, they have been regarded as surpassing the lungs in efficiency. Gill efficiency, however, depends on the rate at which water passes over them. Gill respiration in a sense represents a stage of cutaneous respiration, and gills are structures which increase the area and efficiency for gas transport across the respiratory surface. They show considerable modifications with change in Oxygen environment, and frequently function in combination with other respiratory structures in the exchange of vital gases. The adaptability of fishes for the procurement of Oxygen is exemplified by the many modifications which have evolved to alleviate limitations imposed by simple diffusion. Many of these adaptations permit air-breathing, allowing some obviously aquatic teleosts to become temporary land dwellers. Aerial respiration provides an example of a fundamental change in the functioning of one of the main organ systems of the body and also in the resultant modifications of the correlated structures. The part of the circulatory system which is intimately connected with the respiratory organs, shows modifications with the development of the accessory respiratory organs.

On searching through the literature on the subject, one cannot fail to be struck by the fact that detailed studies on the circulatory system of freshwater Teleostomi in general and the efferent branchial and the venous system in the respiratory region in particular have been greatly neglected.

The outstanding contributions, on the circulatory system correlated with the varied adaptations of the respiratory mechanism in freshwater fishes, are mainly by Hyrtl (1853) and Burne (1896) on the aortic arches of *Saccobranchus* (*Heteropneustes*) *fossilis*, Lele (1932) on the circulation of blood in the air-chamber of *Ophicephalus punctatus*, Wu and WeiChang ('46) on the arterial system of gills and supra-branchial cavities of *Ophicephalus argus*, Nawar ('55) on the vascular system of *Clarias lazera*, Das and Saxena ('56) on the circulation of blood in the respiratory region of *Labeo rohita* and *Ophicephalus striatus* and Saxena ('56) on the afferent and efferent branchial arteries of *Mastacembelus armatus*, *Rita rita* and *Anabas testudineus*. But to my knowledge no detailed account of the circulation of blood in the respiratory region of *Anabas testudineus* exists.

I am greatly indebted to Dr. S. M. Das, D.Sc., F.A.Z., F.Z S.I., F.N.A.Sc., F.Z.S. (Lond), Department of Zoology, Lucknow Univertity, for his keen interest and continuous guidance throughout the progress of this work. My thanks are also due to Principal S. P. Saxena and Prof. K. K. Varma of D. A. V. College, Kanpur, for the facilities provided in the institution.

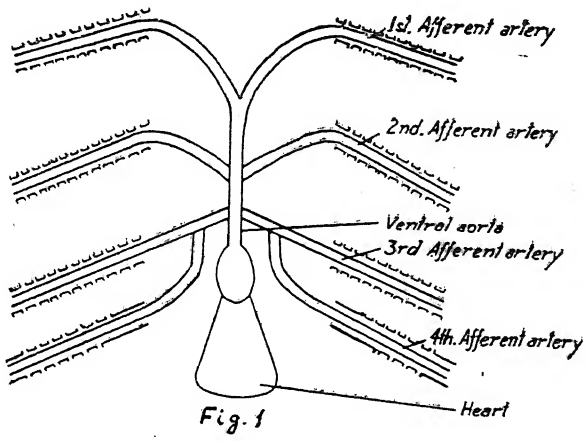
II. MATERIAL AND TECHNIQUE

The live specimen were procured from Calcutta. The afferent arteries were injected through the ventral aorta by gum arabic carmine and gelatin carmine mass and was fixed in alcohol for a week and then dissected. Starch carmine mass was found unsatisfactory in these fishes. The injection mass was given while the heart was still beating to ensure proper circulation of the injection mass into the finest vessels. The efferent and venous systems were not injected, as the fish after being

narcotized or rapidly killed and placed in 70 percent alcohol or 10 percent formalin and glycerine mixture showed the finest vessels on dissection after a week distinctly, due to coagulation of blood in them. All the dissections were done with the help of a stereoscopic binocular microscope to expose in detail the finer blood vessesls. The blood vessels were traced into and across the respiratory surfaces and accurate line drawings made from the dissections.

III. AFFERENT BRANCHIAL ARTERIES

The bulbus arteriosus continues anteriorly as the ventral aorta (Fig. 1). The ventral aorta after piercing the pericardium anteriorly, runs forward in the mid-ventral line along the under surface of the floor of pharynx. It extends from the ventral end of the third gill arch upto the mid-distance between the ventral ends of the second and first gill arches, where it terminates by bifurcating into the first pair of afferent branchial arteries. Along its course, in level with the ventral end of the second gill arch, the ventral aorta gives off the second pair of afferent branchial arteries. Just after piercing the pericardium, a little anterior to the ventral end of the third branchial arch, the ventral aorta gives off the third pair of afferent branchial arteries. After a short distance of its origin the third afferent artery of each side gives rise from its dorsal aspect to the fourth afferent branchial artery which is smaller than the former. The fourth afferent artery runs vertical to the third afferent artery for some distance before it curves posteriorly.



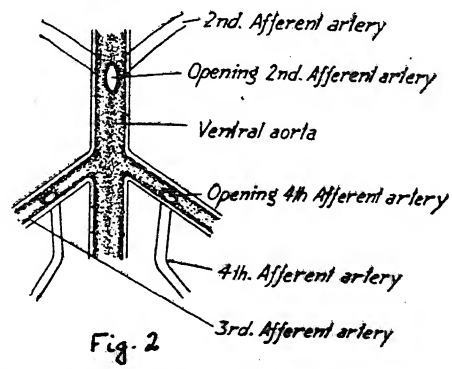


Fig. 1. Afferent arteries of *A. testudineus*.

Fig. 2. Ventral aorta cut open to expose the openings for the second, third and fourth afferent arteries of *A. testudineus*.

The first pair of afferent arteries originates by the bifurcation of the ventral aorta anteriorly, while the second pair of afferent arteries orginates from a single aperture in the dorsal wall (Fig. 2) of the ventral aorta. Immediately after piercing the pericardium the ventral aorta gives off the third pair of afferent arteries from separate openings in the lateral walls. The fourth afferent artery of each side originates from the roof of the third afferent artery of its side. Thus, the fourth pair of afferent arteries do not arise directly from the ventral aorta but from the third afferent arteries. The ratio between the distances of origin of the first and second pair of afferent arteries from the conus is always 3:1 and the third afferent artery originates immediately after the conus which later gives rise to the fourth pair of afferent arteries.

All these afferent arteries run for a distance along the ventral surface of the floor of the pharynx before traversing their corresponding branchial arches, where they run along the grooved outer surfaces and lie externally to the efferent branchial arteries. During its course along the gill-arch, each branchial artery gives out a series of paired afferent lamellar arteries corresponding to the number of gill-lamellae present. The fourth pair of afferent arteries gives out only the anterior series of afferent lamellar arteries and few of the posterior series. Each afferent lamellar artery communicates with the efferent lamellar artery through cross vessels and capillaries.

IV. EFFERENT BRANCHIAL ARTERIES

The blood from each lamella and its secondary folds is collected by the efferent lamellar artery. The efferent lamellar artery runs along the outer edge of each lamella and opens proximally into the efferent branchial artery. In each gill arch there is a pair of efferent branchial arteries — the pretrematic and posttrematic, situated on either side of the afferent arteries on the ventral side of the ceratobranchial. Pretrematic artery receives the efferent lamellar arteries from the anterior row of gill-filaments and the posttrematic from the posterior row of gill-filaments of the same gill-arch. The pre-and post-trematic arteries of each gill-arch unite at the lateral tip of the ceratobranchial into a single efferent artery. The first and second pair of efferent arteries leave the arch at the postero-dorsal end and break up into numerous capillaries to supply the labyrinthine organ and the branchial chamber respectively. Thus, the first and second pairs of efferent arteries donot communicate with the circulus cephalicus in any region.

The first supra-branchial artery gives out anteriorly the anterior carotid and the orbito-nasal artery of its side (Fig. 3). The third efferent artery on leaving the postero-dorsal end of the third gill-arch, curves round the fourth internal branchial cleft and runs posteriorly to meet the fourth efferent artery of its, side, the two together forming the second supra-branchial artery. The second supra-branchial artery runs inwards to meet the first supra-branchial artery in the region of the basi-occipital bone. The right second supra-branchial artery gives rise to the coeliaco mesenteric artery before its union with the first supra-branchial, there being no corresponding vessel on the left side. The dorsal aorta is formed by the junction of the first and second supra-branchials of the left side and the transverse commissural vessel (posterior commissure). Thus, the dorsal aorta does not arise from a central position but asymmetrically from the left side. It curves towards the mid-ventral line of the body before running posteriorly. Finally the right and left supra-branchial arteries are joined together by the posterior commissure in the region of the basi-occipital bone.

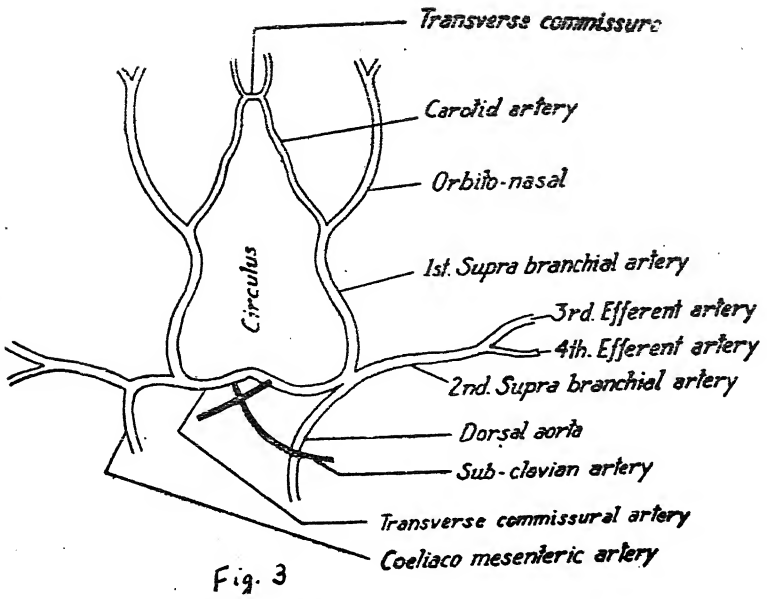


Fig. 3. Efferent system in the respiratory region.

The posterior commissure gives out from its right side a single sub-clavian artery which runs posteriorly and curves to the left side supplying the muscle groups situated in the posterior region of the branchial chamber. Another sub-clavian artery is also given out from the left side adjascent to the first sub-clavian which crosses the former dorsally and supplies the muscles of the right side.

Only the third and fourth efferent arteries communicates with the *circulus cephalicus* through the second supra-branchial artery, while the first and second efferent arteries do not communicate with the circulus or the dorsal aorta. The transverse commissure (anterior commissure) joins the carotid arteries of the two sides. Thus, the circulus is formed by the anterior commissure anteriorly, the first supra-branchial arteries laterally, and the posterior commissure posteriorly.

The anterior commissure in the circulus has been named as the transverse commissure by Ridewood (1899), although the term anterior commissure should be preferred. While the posterior commissure in such fishes where it is present was termed transverse commissural artery by Lele (1932), in this case also the name posterior commissure is preferable.

V. VENOUS SYSTEM

The venous blood from the respiratory region is collected by the paired anterior cardinal veins and a single inferior jugular vein (Fig. 4). Each antorior cardinal vein is formed by the union of the orbito-nasal, labyrinthine, and branchial veins. The orbito-nasal vein begins by collecting blood from the eye and the adjascent parts, traverses the orbit and then comes to lie on the ventral surface of the cranium in the branchial chamber above the dorsal extremities of the branchial arches. During its course it receives vessels bringing blood from the brain and other parts of the head.

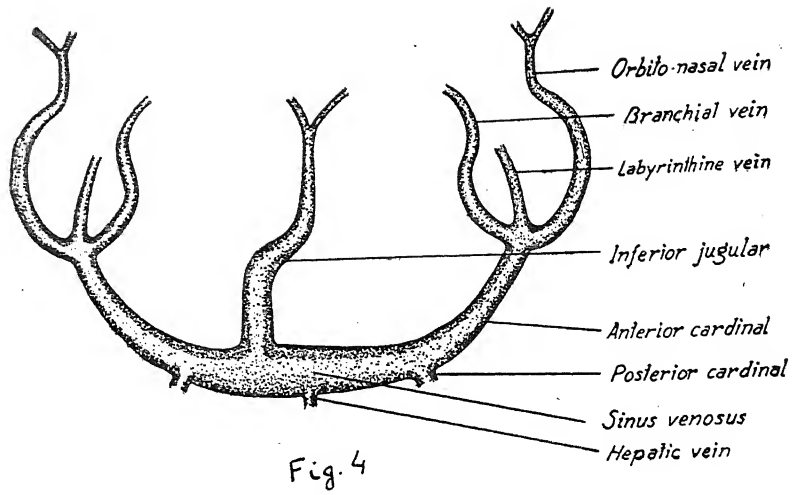


Fig. 4 Venous system in the respiratory region.

The labyrinthine vein is formed by a number of smaller veins which collect blood from the labyrinthine organ. The branchial vein is formed by a large number of small veins bringing blood from the membrane lining the branchial chamber. After receiving the labyrinthine and branchial veins at the same level each anterior cardinal emerges out of the branchial chamber. It curves downwards to run along the outer surface of the posterior part of the cleithrum which it pierces and enters the antero-ventral part of the pericardial cavity to open into the sinus venosus at its antero-lateral extremities. Before opening into the sinus venosus the anterior cardinal of the right side receives a single inferior jugular vein, the left being absent.

The right inferior jugular vein is formed at the anterior end of the floor of the buccal cavity by the union of the branches from both sides of the hyoid arch. It runs posteriorly in the mid ventral line till it reaches the bulbus arteriosus, where it curves towards the right and runs along side of the heart and finally opens into the right anterior cardinal vein.

VI. BLOOD SUPPLY OF THE LABYRINTHINE ORGAN AND BRANCHIAL CHAMBER

The first pair of efferent arteries after leaving the first gill-arch (Fig. 5) at the posterio-dorsal end divide immediately into two main branches. One of the branches divide and subdivide to supply the labyrinthine organ, and the other branch curves anteriorly along the anterior wall of the branchial chamber to supply the lining membrane of the anterior and dorsal side of the branchial chamber. The second pair of efferent arteries after leaving the gill-arch runs along the posterior surface of the branchial chamber. After running for a short distance it divides into two main branches, one supplying the lining membrane of the posterior and lateral surfaces of the branchial chamber and the other supplying the lining membrane of the mesial and ventral surfaces of the chamber.

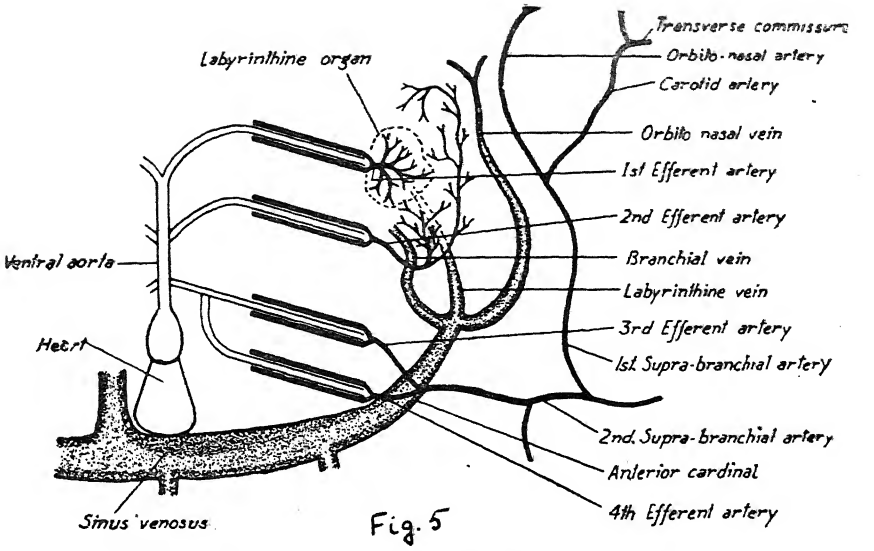


Fig. 5. Afferent, efferent arteries and veins to and from the gills, branchial chamber and the arborescent organ.

The blood from the labyrinthine organ is collected by many small veins, which join to form a single large vein—the labyrinthine vein. It runs posterioly to meet the anterior cardinal. The blood from the lining membrane of the branchial chamber is collected by a number of small veins which join to form a single large vein termed as branchial vein. The branchial vein runs posteriorly to meet the anterior cardinal at the junction of labyrinthine and orbito-nasal veins. The blood supply of the labyrinthine organ and the lining membrane of the branchial chamber, which is important to the fish that by this means it is enable to perform aerial respiration almost all the time, is given in Table I.

TABLE I.

CIRCULATION OF BLOOD IN THE LABYRINTHINE ORGAN AND BRANCHIAL CHAMBER

Regions	Blood supplied by	Blood collected by
Labyrinthine organ ...	1st Efferent artery	Labyrinthine vein
Anterior wall ...	Branch of the 1st efferent artery	Branchial vein
Anterior wall ...	Branch of the 2nd efferent artery	,, ,,
Posterior wall ...	,, ,, ,, ,,	,, ,,
Mesial wall ...	,, ,, ,, ,,	,, ,,
Lateral wall ...	,, ,, ,, ,,	,, ,,

VII. COURSE OF CIRCULATION OF BLOOD

The blood collected in the sinus venosus through the anterior cardinals is mixed, the deoxygenated from the various parts of the head and oxygenated from the labyrinthine organ and the branchial chamber, and the deoxygenated through the posterior cardinals and the hepatic veins, is passed to the ventral aorta through the ventricle. In this way it is the mixed blood which is sent for aeration from the heart through the ventral aorta to the gills by the four pairs of afferent arteries. The oxygenated blood from the gills is collected by the efferent erteries (Fig. 6). This blood from the first two gills is supplied through the first and second efferent arteries to the labyrinthine organ and the lining membrane of the branchial chamber for further oxygenation, from here the blood is collected by the labyrinthine and branchial veins and sent through the anterior cardinals to the heart. Thus, the oxygenated blood from the first and second gills, the labyrinthine organ and the lining membrane of the branchial chamber is not sent for circulation directly through the dorsal aorta but is returned to the heart. The mixed blood passing through the third and fourth gills is partly oxygenated as on the fourth gill-arch very few gill-filaments are present. This blood then passes to the dorsal aorta through the second supra-branchial artery of the left side and the posterior commissure which collects blood from the second supra-branchial artery of the right side. The blood is sent to anterior region through the first pair of supra-branchials and to the posterior parts of the body through the dorsal aorta and to the alimentary canal and associated structures through the coeliaco-mesenteric.

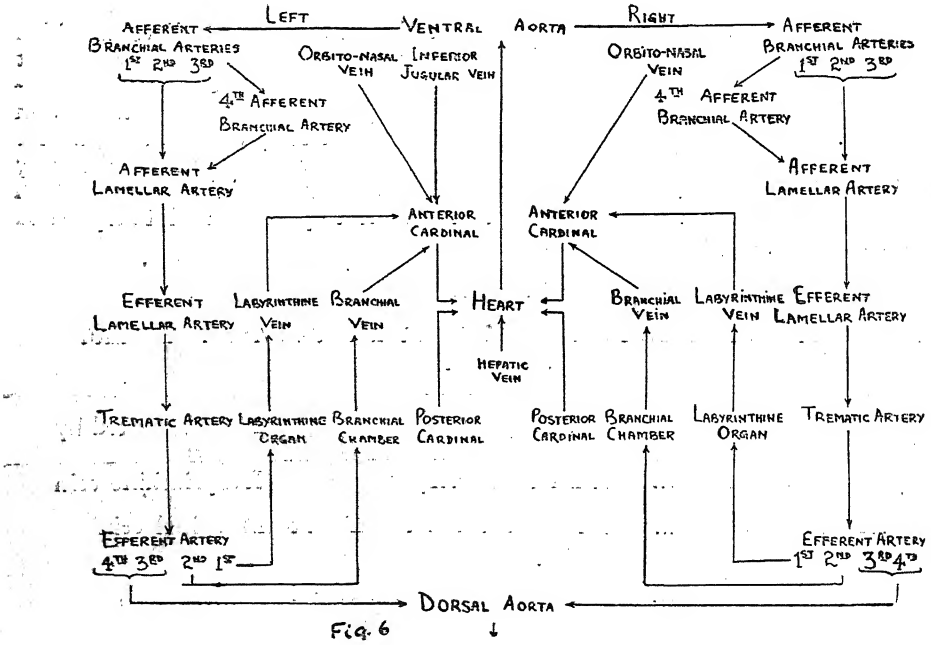


Fig. 6. Course of circulation of blood.

VIII. DISCUSSION

The ramifications in the chief blood vessels of the respiratory region in fishes with accessory respiratory organs have, however, not been satisfactorily worked out

in freshwater fishes of India. Carter and Beadle (1931) while discussing the blood supply of the respiratory organs in fishes, went to the extent of saying 'that the arterial supply of the respiratory organs as a rule, is not of great interest..... and if the accessory, organ is on direct course of branchial circulation (as in *Hypopomus, Clarias*, and *Saccorbranchus* etc.) it is to be expected that no modification of either the main venous or arterial circulation would occur.' Das (1940) maintained that the arterial supply of blood in air-breathing fishes is not of any special interest. In reviewing the date compiled by Carter and Beadle (1931) it is at once obvious that the accessory respiratory organs of the air-breathing fishes are supplied by blood of multiferious origin. It would seem that there are two possible factors governing the resultant blood supply, namely, the initial organ from which the accessory organ is derived, and the morphological situation of the accessory organ. It matters little what kind of blood the vessels may contain.

The third pair of afferent arteries originates from separate openings in the lateral walls of the ventral aorta. The fourth afferent artery of each side originates from the roof of the third afferent artery. Thus, the remarkable condition, recorded to my knowledge for the first time among teleosts, exists that the fourth afferent arteries donot arise directly from the ventral aorta but from the third afferent arteries. It may be that the blood supply to the fourth gill-arch through a branch from the third afferent artery indicates the reduction and loss of the fourth afferent artery entirely, leaving the third afferent artery to supply the third as well as fourth gill-arch. But it may be that the fourth afferent has shifted its origin and comes to lie on the third afferent artery. It appears that this peculiar arrangment is correlated with the reduction of the fourth gill-arch.

The elaboration of the efferent branchial system, espacially those vessels arising from the circulus cephalicus, have not been traced in the past in any detail, except by Ridewood (1899) who, during his extensive studies on the efferent blood vessels of teleostean fishes, divided the efferent branchial arteries into four main groups according to their relation with the circulus cephalicus. In Ridewood's groups all the four pairs of efferent arteries communicate directly or indirectly with the dorsal arota. But in *Anabas* the first and second efferent arteries do not communicate with the circulus or dorsal aorta at all and a similar condition has been reported in *Ophicephalus striatus* (Das and Saxena, 1956).

In *Anabas* the first and second pairs of efferent arteries breakup into capillaries into the labyrinthine organ and the lining membrane of the branchial chamber and donot communicate directly or indirectly with the dorsal aorta, and the blood from the accessory respiratory organ is sent to the heart directly. Such an arrangement was unknown to Ridewood. The similar cases are that of *Monopterus javanensis* (Wu and Lin, 1243), in which the third efferent arteries alone and of *Ophicephalus striatus* (Das and Saxena, 1956) in which the first and second efferent arteries fail to reach the circulus or the dorsal aorta. In these three exceptions the efferent arteries, which are disconnected with the circulus and the dorsal aorta, are distributed entirely to the accessory respiratory organ and branchial chamber, as in *Anabas* and *Ophicephalus* or partly as in *Monopterus*. Therefore, the conclusion seems justifiable that the deviation from their usual path of these arteries is correlated with the peculiar secondary adaptation to aerial respiration and the elaboration of the secondary organs of respiration in that region.

In *Anabas* the coeliaco-mesenteric artery does not arise directly from the dorsal aorta, but is connected with the latter through an intervening posterior commissure, a condition already reported in *Ophicephalus striatus* (Das and Saxena, 1955) and *Mastacembelus armatus* (Saxena, '56) It is also remarkable that the dorsal aorta does not arise centrally but from the left side alone. Furthermore, it is from the

intervening posterior commissure that the sub-clavian arteries of both sides originate. Such an aberrant arrangement of arteries among teleosts was first described in *Tetradon* (Ridewood, 1899). This unusual arrangement of coeliaco-mesenteric, the dorsal aorta, and the sub-clavian has to be satisfactorily explained in so widely separated groups of teleosts.

In *Anabas* the body receives the mixed blood as the blood passing through the fourth gill-arch is not properly aerated due to the reduction in size and number of the gill-filaments, The anterior cardinals bring the mixed blood to the heart as the blood supplied to the labyrinthine organ and the lining membrane of the branchial chmaber by the first and second efferent arteries is also collected during its course.

IX. SUMMARY

The second afferent arteries originate from a single aperture and the third afferent arteries from independent apertures. The fourth afferent arteries originates from the dorsal aspect of the third afferent arteries. The first and second efferent arteries supply the labyrinthine organ and the lining membrane of the branchial chamber after supplying the gill-filaments of the corresponding branchial arch. These two efferent arteries donot communicate with the dorsal aorta directly or indirectly. The blood from the accessory respiratory organ is collected by the anterior cardinals during its course through the branchial chamber. The blood collected in the heart is mixed. The blood sent for circulation to the body and head through the dorsal aorta and the first pair of supra-branchial arteries is not fully aerated.

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